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Science Policy: Problems and Trends

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ПОЛИТИКА В ОБЛАСТИ НАУКИ:
ПРОБЛЕМЫ И ТЕНДЕНЦИИ
На английском языке

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Author's Note

The social significance of science under the scientific and technical revolution, and with it the role of the modern state's science policy tend increasingly to grow.

The rapid growth of the Earth's population has not in any sense been attended with a similar increase in its vital resources, whose stocks do not increase to the necessary proportions of themselves. This growth can be brought about only by complementing the "mankind-Earth" system with the "Earth-Universe" metasystem, and the latter can be realised only through the medium of science, its latest discoveries and the innovations based on these.

It is impossible to preserve and develop the Earth's biogenosphere unless it is complemented with the noosphere. That is the only way to preserve its vital resources from damage and depletion, and simultaneously to reduce the scale and consequences of natural disasters and to prevent artificial disasters.

The USSR has gained much experience in planning and organising science.

Article 26 of the new Constitution (Fundamental Law) of the Union of Soviet Socialist Republics, adopted by the Seventh Extraordinary Session of the USSR Supreme Soviet on the 7 October 1977, states:

"In accordance with society's needs the state provides for planned development of science and the training of scientific personnel and organises introduction of the results of research in the economy and other spheres of life."

Article 131 envisages that "within its powers the Council of Ministers of the USSR shall: ... draft and

implement measures ... to develop science and engineering, to ensure rational exploitation and conservation of natural resources ... provide general direction in regard to ... economic, scientific and cultural co-operation of the USSR with other countries. ..."

The socialist planned economic system has quite naturally pioneered both scientific policy, that is, policy based on science, and science policy. Socialism has created the objective conditions for doing this, and the translation of these conditions into reality is backed up with a powerful scientific and technical potential. US journal *Science* says in an editorial that planning in the USSR ensures balanced and stable development of science in a better way than it is done in the USA (*Science,* November 19, 1976). At the very start of the current decade, the Soviet Union outstripped the United States, the most developed capitalist country, in R & D outlays as a share of the gross social product, and also in the number of scientists and engineers engaged in R & D per 10,000 population. [1]

In 1977, the USSR is to spend 18,200 million rubles on research, or 7.7 per cent of the planned expenditures under the state budget, as compared with 4.3 per cent in 1967. [2] The US Federal Administration's obligations to finance R & D in fiscal 1977 are projected at 23,500 million current dollars, or 17,000 million in terms of 1972 dollars, discounted for inflation. This comes to only 6 per cent of the federal budget, as compared with 10.7 per cent in fiscal 1967. [3] Consequently, both in absolute and relative terms, the financial component of the US scientific and technical potential falls short—especially in dynamics—of that of the USSR. The same applies to the personnel component of this potential: the total number of Soviet scientific workers is still one-quarter of the world's total, while that of the United States is not more than one-fifth (not counting the foreign scientists working in the United States).

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[1] *Science Indicators 1972,* NSB, Washington, 1973, pp. 4, 5, 102, 103.

[2] *Pravda,* October 28, 1976; *The Economy of the USSR in 1967,* Moscow, 1968, pp. 888, 889 (author's computation).

[3] *Science Research Studies Highlights,* NSF 76-317, Washington.

Of course, this does not in any sense minimise the high scientific level of the researchers working in the United States. Research by scientists in various countries tends mutually to complement each other, helping to tackle the unprecedentedly complicated problems facing mankind. *Christian Science Monitor*, a reputable US newspaper, had every reason to devote its issue of November 18, 1976, to an important topic, "How joint US-Soviet research helps both". The global scale of these problems requires global-scale integration of mankind's intellectual and material efforts to safeguard its terrestrial habitat, to develop the resources of the World Ocean, and to secure the further existence and development of our civilisation.

If the tasks facing mankind are to be tackled successfully, there must be a final end to the military confrontation between the two socio-political systems. In his reply to the questions submitted by the US political analyst J. Kingsbury-Smith on the eve of 1977, L. I. Brezhnev said: "This is the 60th year of the existence of the Soviet state, which was born under the sign of Lenin's famous Decree on Peace. Of course, one should like to see this year marked with fresh major steps in preserving and consolidating peace, further asserting peaceful coexistence as the only reasonable, the only acceptable norm in relations between states.

"Historical experience confirms that our two countries, acting in accord with common sense and taking account of the responsible position of each in the modern world, can make an important contribution to the cause of peace and the development of mutually beneficial cooperation."

Science policy evolution of states determines ever more markedly the character of international relations today.

In this book I have tried to make a comparative analysis of science policy in the USSR and the USA, and in several other countries.

My starting point was the principle of complementarity, borrowed from physics (Bohr), mathematics (Gödel) and cybernetics (Beer). Scientific organisation is regarded as the external complement of individual researchers and their relationships, including the conflict between research nonconformism and organisational con-

formism; the science network as the external complement of individual scientific organisations and their relationships. The state's science policy is the external complement of the science network and its component scientific organisations and their scientists and engineers engaged in R & D. The multitiered structure of present-day science policy is complemented from outside with a system of scientific and political functions. For its part, the current scientific and technical revolution brings to the fore the strategy of directing scientific activity in its relationships with society, ranging from the "society-nature" metasystem to the "forms and functions of R & D" subsystem.

Periodic pulsations of scientific activity acquire crucial importance for the dynamic of the "science-society" metasystem which describes science policy.

It goes without saying that the various aspects of the theory of science policy which I have dealt with in this book require further research to shed a fresh light on the ways of enhancing the efficiency of the scientific and technical component of the intellectual potential.

Chapter One

Conceptions and Terms. Subject and Method

The science policy theory is faced with some difficulties in agreeing the various conceptions, which are largely due to the lack of a common idiom that theorists could use among themselves and with practitioners. Successful elaboration of the subject and method of the science of science is hampered by various obscurities, different readings of terminology. Only fully and clearly formulated problems in the organisation and administration of science can be subjected to scientific analysis and adequate solution. For, "Crafty men condemn studies; simple men admire them; and wise men use them: for they teach not their own use: but that is a wisdom without them, and above them, won by observation." [1]

Conceptions and Terms

The elaboration of an effective policy in the sphere of science requires a simple definition of the basic conceptions in the organisation and administration of science. Any confusion between conceptions of differing content and volume, any incorrect use of terms and terminological confusion in the organisation and administration of science exert a drag on the development not only of the theory but also of the practice of science.

Of course, the complete ordering of the terminology in science organisation is a task that will call for extensive and special research. For the time being, one could suggest a number of working definitions of the basic

[1] *The Works of Francis Bacon*, Vol. II, London, 1826, p. 361.

conceptions in the organisation and administration of scientific activity.

On the strength of the etymology of the term "*science*" in Russian, we take it to mean, first, a system of knowledge accumulated by a given point in time in every sphere of the exact, natural and social sciences; second, the endless process of cognition in its dialectical development. Epistemologically, these two aspects of science are connected with each other like relative and absolute truth. Science helps to order the knowledge already gained and so sets its limits (relative truth), and thereby also the line of further cognition (advance towards absolute truth). Consequently, the two-fold nature of science is latent with a contradiction which serves as the inner source of its motion, its self-development.

But the self-development of science expresses only one degree of its freedom. The second degree of its freedom springs from the fact that science is socially determined. Science is made by men, who are members of human society, and it is impossible to live in a society and be entirely free of it. The fact that science is socially determined is connected with its self-development as closely as the system of knowledge with the process of cognition. [1] This connection is reflected in the conception of "*scientific activity*".

We take scientific activity to mean an aggregation of the processes in which new scientific knowledge is obtained, transferred and used, together with the objective and subjective conditions in which they proceed. From the economic standpoint, scientific activity may be called the extended social reproduction of knowledge,

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[1] The self-development of science is, in effect, an expression of mankind's deepest social need, which is to "know in order to be able". The development of this need has gone hand in hand with the formation of man and human society as the first force in the evolution of nature which has actively, instead of passively, adapted itself to the environment. The urge for ever fuller and more authentic knowledge is inseparable from mankind's social progress. In our day, the acquisition of knowledge becomes first an equal and then the leading branch of social production. As Marx foresaw, the production process is becoming a sphere in which science is being applied, and, conversely, science is becoming a factor and, one might say, a function of the production process.

which includes its own material, spiritual and emotional premises.

In economic terms, the conception of "scientific activity" is more extensive than that of "science". Thus, even in 1940, the number of scientists and engineers in R & D [1] in the USSR totalled 98,300, while the total number of those employed in science and scientific servicing came to 362,000, that is nearly four times as many. The ratio of 1 to 4 and 1 to 3 has been maintained over a period of more than three decades not only for the number of researchers and the number of those employed in science and scientific servicing. We find the same ratio being maintained for the number of persons holding scientific degrees to the total number of researchers.

Table I-1

Number employed (1,000)	1960	1965	1970	1975
Total in science and scientific servicing	1,763	2,625	3,238	4,046
Including researchers	354	665	928	1,223
Including those with scientific degrees of candidates and doctors of science	109	149	248	359

Source: *The Economy of the USSR in 1975*, pp. 165, 533; *The USSR in Figures in 1976*, Moscow, 1977, pp. 83, 178 (in Russian).

[1] It is Soviet statistical practice to include in the number of researchers academicians, full members and corresponding members of all the academies; all persons holding the scientific degrees of doctors and candidates of science or the scientific title of professor, assistant professor, senior research associate, junior research associate and assistant, regardless of the place and nature of their work; persons engaged in research at scientific establishments and in teaching and scientific work at institutions of higher learning, regardless of whether they have a scientific degree or scientific title, and also specialists without scientific degrees or scientific titles but engaged in research at industrial enterprises and in design organisations (*The Economy of the USSR in 1975*, Moscow, 1976, p. 780, in Russian).

Together with those working in education and culture and in design and prospecting organisations, who are also involved in scientific activity, the number of those employed in this area will probably be as high as 5 or 6 million. Let us note, by way of comparison, that in 1975 motor, urban electric-driven and other transport and cargo-handling operations involved 6.4 million persons. Let us recall that employment in scientific activity had been growing at a record pace, which is many times higher than that in other branches of the national economy. [1] This is a direct expression of the transformation of social production under the scientific and technical revolution.

Scientific activity not only comes to be a major and highly important branch of the economy but also exerts an ever growing "multiplicator" effect, as it permeates every branch of the economy and so enhances their efficiency. It is no longer a small circle of researchers but broad masses of working people that are concerned with the development of science, with servicing it and making use of its achievements. For them, scientific activity becomes the main line of endeavour, even if this does, quite naturally, occur in varying degree and form, and at different skill and creative levels.

The synthesis of science and organisation helps to transform scientific activity at every level of its structure. As science becomes one of the leading occupations in modern society, and especially with the development of "Big Science" in large-scale projects involving thousands of personnel, the structure of scientific activity tends markedly to be complexified in the form of a multitiered hierarchy.

With the growth of the collective nature of this activity, the role of the primary structural unit in science passes from the individual researcher to the organised research team of the laboratory, sector, department, and so on. These primary research organisations constitute the lower tier, the *microlevel* in the organisation of science, whose fundamental and prime importance in the production of scientific knowledge has been maintained and

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[1] *The Economy of the USSR in 1975*, p. 583.

consolidated with the merger of laboratories into research institutes.

Institutionalisation in science has coincided in time with its growing national, political, military and economic importance. This has given rise to individual government agencies vested with various scientific and technical functions, and these are gradually harnessed into a system. Thus, the institutionalisation of scientific activity is followed by the institutionalisation of government policy in the sphere of science involving a system of measures in the administration of scientific activity. This is the *macrolevel* of scientific organisation, and its highest and governing tier.

The micro- and macrolevels in the organisation of science interact through the intermediate level of a network of scientific centres and institutions. This network is formed by the science policy agencies on the basis of the existing and newly established centres and institutions. Its purpose is to ensure more favourable conditions for the generation of new scientific ideas and their most rapid development and application. The scientific network constitutes the *metalevel* in the organisation of science, a kind of middle tier.

On this trinity of levels is based the organisation of scientific activity as a complex probability open-ended system consisting of a multiplicity of structural elements with interconnected functions. Organisation may be seen as the formation (creation) of efficient structures. [1] *The organisation of scientific activity* is, first, the given state of the system (organisation-I), second, the desired state at a future moment of time T (organisation-T), and third, the process of the transformation of organisation-I into organisation-T, but in this sense the organisation of scientific activity on the whole coincides with administration.

The administration of scientific activity is, consequently, a complex of functions ensuring the existence of organi-

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[1] V. A. Pokrovsky, "Problems in Improving Economic Methods in the Administration of Scientific and Technical Progress". In: *Proceedings of an Interrepublican Scientific Conference on the Economic Questions in Scientific and Technical Progress,* Section I, Yerevan, 1973 (in Russian).

sation-I and its transformation into organisation-T with the smallest expenditure of time and effort.

Within the functions of administration it is possible, I think, to identify direction, planning, coordination, control and regulation.

The substance of *direction* is the choice of purpose and of the criteria for organising activity in order to achieve it. The correct choice of purpose and criteria is of practical importance for administrative decision-making. In general terms, the correctness of this choice is the function of the full use of information to evaluate the existing state of things and to prognosticate the future. But, as a rule, there is never enough time to meet these conditions, because time and again decisions have to be taken in an atmosphere of urgency. Nor is this surprising: indeed, it is the emergence of such a situation which usually produces the need for urgent decisions, which means, choice. A surgeon deciding to operate at once without the benefit of the history of the case must rely mainly on intuition. Similarly, political decisions, notably in the sphere of science, have to be taken on some occasions. In other words, in the sphere of direction the objective and subjective aspects are closely interwoven: the use of objective conditions itself depends on the personal qualities of the director, and on his scientific, technical and administrative competence.

For that reason alone, "direction" is considerably narrower than "administration" as a term and cannot be used instead of the latter, except with special reservations, because one element of a system cannot represent the system as a whole.

The next, equally important element of administration is *planning*. This means above all, though not exclusively, the elaboration of an optimal way in the given conditions towards the set goal with the observance of the established criteria. Planning is normative, [1] because

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[1] That is normative which is subject to a norm regarded as an independent variable—usually the goal attained by fulfilment of the plan. The ways and means of achieving the goal constitute the sum total of the functions of planning (see, V. G. Afanasyev, *Social Information and the Governance of Society,* Moscow, 1975, pp. 119-20, in Russian).

it is purposeful. This means that planning has to evaluate the present on the strength of future criteria. But under the scientific and technical revolution the pace of development is such that the future tends to become the present virtually faster than the present recedes into the past. This is an inducement to plan scientific and technical progress for longer and longer periods and to orient it upon ever more remote goals. But this kind of planning must coalesce both with normative and with explorative scientific and technical prognostication (which runs from the present into the future). Long-term, medium-term and current plans for developing scientific activity can now be elaborated only on the basis of long-term complex prognostication.

Because of the complexity of the scientific and technical systems being planned, planning itself has to be systemic. The reality of the plans directly depends on the extent to which the whole complex of factors affecting scientific activity is taken into account, on the timely elaboration of all the necessary back-up measures and the coordination of all the required efforts. That is the function of *coordination*, which concerts the division of labour in the process of plan realisation. A specific feature of our time is a continuous extension of the sphere of coordination not only beyond departmental but even national boundaries, as will be seen from the Comprehensive Programme for the Further Extension and Improvement of Cooperation and the Development of Socialist Economic Integration by the CMEA Member Countries. Within its framework, its members have been working on a plan for coordination of scientific and technical research which is of mutual interest.

But the most perfect plans are worth very little indeed unless they are fulfilled. Verification of fulfilment of planned targets is effected by means of *control.* This is above all a way of maintaining the functioning of the system by means of feedback signalling any departures from the established parameters, which helps to return them to the norm. Like direction, planning and coordination, control is a narrower term than administration, although in English both are frequently designated by the same term, namely, control. It has been well established that the absence or laxity of control has a negative effect

on the productivity of scientific work. But excessive financial and administrative control, especially at the stage of pure and explorative basic research, may have an equally negative effect on it. Consequently, differentiated and flexible control is a necessary condition for its efficiency.

The feedback control mechanism in the administration of scientific activity is supplemented with *regulation,* which makes it possible to modify the functioning of the system and to transform it in accordance with the circumstances not envisaged in the plan. Consequently, regulation helps to effect flexible and timely adaptation of "organisation-1" to the changing conditions of the environment. This is a highly responsible function, which helps to maintain an equilibrium (homeostasis) both between the system and the environment (including other systems) and within the given system. In this sense, regulation, while being merely a function of administration, most fully helps to fulfil its primary task, that of ensuring the very existence of the system under control.

Regulation also takes part in fulfilling the second task of administration, that of ensuring the development and improvement (optimisation) of the system, for equilibrium within the system and between the system and the environment must be constantly upset only to be reestablished again and again on a higher level. Consequently, the second task of administration turns out to be inseparable from the first, in each instance constituting a perplexing complex. If the two-fold task of administration defies solution from outside, regulation comes to the rescue, operating as internal *self-regulation* of the system, and relying on the universal capacity for *self-organisation.* V. I. Kremyansky says: "Contrary to the fairly popular view, the capacity for self-organisation is not an exclusive feature of the highest levels of organisation of matter, that is, only of living systems, of society, and of cybernetic automatons within it. On the contrary, the capability for self-organisation (like the forms of self-motion in general) is also widespread in inorganic nature.... It is no exaggeration to say that self-organisation is one of the universal attributes of matter. But, of course, the forms in which this capacity is expressed

are profoundly distinct and differ above all depending on the basic structural levels of material systems." [1]

Here is a typical example: the growth in the scale of the activity of a research institute automatically leads to a growth in its size and to a complexification of its structure. The two-fold task of administration—maintenance of the stability of organisation and its steady improvement—can be fulfilled only if the competence and autonomy of the individual divisions (sectors, departments) are enlarged to a point at which they are allowed to organise themselves into objective-geared problem groups (projects). The importance of self-organisation and self-regulation, to which basic research is especially adequate, tends to grow in scientific organisations together with the role of this research, and as (relatively) less creative types of research and especially R & D projects are algorithmised and automated, and also as the information and communication infrastructure of scientific activity is developed. [2]

Consequently, regulation may be regarded not only as the final but also as the highest function of administration which reveals a tendency to self-organisation, as organisation-I is transformed into organisation-T. In varying degree, this tendency operates at any level of organisation in scientific activity, from the primary research team to state policy in the field of science.

Policy in the field of science is a complex of state measures for the administration of scientific activity ensuring a combination of the functions of direction, planning, coordination, control and regulation which makes it possible to achieve the maximum social efficiency of research and development. State policy in the field of science is inevitably a concentrated expression of the interests of the ruling classes and a reflection of the character of the relations of production [3] in the country. But it

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[1] V. I. Kremyansky, *Structural Levels of Life of Organic Matter*, Moscow, 1969, p. 10 (in Russian).

[2] See, *Questions of the Theory and Practice of Administration and Organisation of Science*, Moscow, 1975 (in Russian).

[3] In Marxist political economy, "relations of production" is a term used to designate the relations which are established among men in the social production of material goods, and whose character is determined above all by who owns the

cannot ignore the objective requirements in the development of science as a productive social force in the given country and in other countries of the world. This provides the basis for the development of international scientific and technical cooperation, and the discussion and coordination of lines of policy in the field of science among states not only with the same but also with different social systems.

In 1971, the Science of Science Foundation, set up in Britain by Prof. J. D. Bernal, was renamed the Science Policy Foundation, which meant more than a change of signboard. Scientology emerged in an atmosphere in which science enjoyed growing social prestige everywhere and, one could say, was very much in vogue. But in the late 1960s, the situation underwent a change. With the grave monetary and financial crisis in the USA, Britain and other Western countries, there was a slow-down in R & D appropriations. For the first time in many decades, scientific and technical personnel faced difficulties in finding the right job, and in these conditions the abstract study of the mechanisms and tendencies in the development of scientific activity, even if with the employment of the "methods of science itself", ceased to satisfy those who carried on research and those who financed it. The need for a concrete and effective policy in the field of science came to the fore.

Quite naturally, there was growing worldwide interest in the elaboration of science policy in the Soviet Union, a pioneer in this field, and in the planning of the national economy, and of scientific and technical progress in general.

The object of science policy is scientific activity, which is a complicated dynamic open-ended information system. [1] Epistemologically, scientific activity ensures the development of a system of knowledge in accordance with the advance of cognition. In the social plane, scientific

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means of production. Private property in the means of production makes it possible to exploit the labour of those who own no private property.

[1] The "case of the heretic" who rejects a system of views—the "paradigms", according to Thomas S. Kuhn, does not refute the information model of science but merely shows that this model is of a highly dynamic and not trivial type.

activity operates increasingly as a leading branch of social production where the production of information in general acquires independent importance alongside the production of goods and services. That is precisely the direction along which scientific activity grows and pulsates, as will be seen from its basic parameters in the historical plane. [1]

As a subject of research, scientific activity comprises within a single whole processes which are simple and complex, discrete and continuous, determined and probability, and all of this seriously complicates its quantitative analysis.

This will be seen from its basic categories (or stages, if the process is considered in motion) of research: basic research (pure and objective-geared, or explorative), applied research and development.

The function of basic research is scientific discovery regardless of its possible use in practice, that is, the obtaining of fundamentally new information. Such discoveries are most reminiscent of the short circuits which instantly illumine the fundamental causal nexus between phenomena that had until then been regarded as isolated. The mechanism of scientific discoveries has yet to be fully studied, and the conditions in which they are made are so different that they can hardly be generalised or "averaged out". There is probably hardly any prospect trying to produce quantitative descriptions of the circumstances of fundamental discoveries in terms of cost, inputs of time, etc. The highly intricate creative effort of the scientist defies reduction to simple labour. Now and again, the creative process runs for decades and may become discrete only once, namely, at the moment of discovery. At the same time, it has a clearly probability character, with the probability that the given discovery will be made at this particular time being extremely low. The only guarantee of success is frequently provided by the scientist's name, his reputation as a researcher enjoying the utmost creative freedom. From the standpoint of society, all of this is balanced out by the extremely extensive and profound effect of fundamental scientific discoveries which tend to revolutionise science and ultimately practice as

[1] See Chapter Seven.

well, with relatively minimal inputs, with inputs into applied research an order lower, and inputs into development, two orders lower.

Together with the scale of inputs at these subsequent stages of research there is a sharp growth of the need to apply quantitative analysis, and with it of the possibility of applying it. It is the function of applied research, and especially of development, to make practical application of scientific knowledge and to find ways and means of using the new information. Although here sudden "flare-ups" may also occur, the work is on the whole more balanced and predictable from the standpoint of results. But it is also relatively more labour-intensive, while the labour itself becomes less complex and frequently lends itself to reduction. Large collectives of researchers, developers, engineers, technicians and technologists tackle tasks which are, as a rule, clearly formulated beforehand and divided into stages and functions. Roughly speaking, the researcher's freedom tends to fade with the risk (the uncertainty of the outcome): it is inversely proportional to the growth of the capital and labour-intensiveness of the work. The results which here have to coincide with the pre-set goals are more or less rigidly determined (it is true that even at the applied stage unforeseen problems arise which frequently delay the achievement of the goals by the fixed deadlines). But in breadth and depth of final effect, applied R & D falls short of basic research, although its immediate results and consequences are more obvious and lend themselves to quantitative measurement. When subsidising the applied stage of research, society stands the risk of losing amounts which are dozens of times larger than those involved in its subsidies of the fundamental stages, but the risk is not as great.

Consequently, the sphere of the application of quantitative methods obviously tends to grow from the fundamental end of the spectrum of research towards its applied end, together with the growing need for such methods. This applies to the process in which scientific information is obtained, processed and used.

But according to the definition offered at the beginning of the chapter, the subject of the science of science—scientific activity—also covers the objective and the subjective conditions of the process. To what extent are

quantitative methods applicable in this area? There is no difficulty about the answer if we consider such key conditions of research as organisational, economic, social, historico-logical and psychological conditions. The sphere in which quantitative methods are applicable evidently tends to dwindle from the beginning of the list towards the end, although, generally speaking, the study of all these conditions has barely gone beyond the descriptive stage. It is less evident that in the study of the conditions of research the direction of the applicability vector for the quantitative methods is, in effect, the same as it is in the study of the research process itself, because basic research depends above all on psychological (individual) and historico-logical conditions, and applied research and development, on social, economic and organisational conditions.

For a more detailed clarification of the limits within which quantitative methods may be applied in the science of science there is need to pass from its subject-matter to its method.

Quantitative and Mathematical Methods

Like its subject-matter, the method of the science of science has a complex character, for it is, in effect, not yet a coherent method or even a system, but is rather an aggregation of particular methods, which are, for the most part, also descriptive. The methods used in the study of the organisation of scientific activity and its economics do not have too many common features with the methods used in the historico-logical and psychological analysis of creative scientific endeavour. At any rate, they do not lead to a common quantitative denominator, with quantitative analysis in the science of science having an ancillary role to play for the time being. Meanwhile, the idea is that it should permeate and cement all the particular methods, for only then, strictly speaking, will "the study of science with the methods of science itself" become a reality.

The tendency towards a strictly coherent method is already making headway, but I do not believe that this method will be a purely quantitative one, although it will evidently be a mathematical one.

At this point there is need to put in a reservation. Contrary to the widespread usage, mathematical methods do not boil down to quantitative methods. Indeed, the latest and most important departments of modern mathematics (or metamathematics), like topology, mathematical logic, the theory of sets, and so on, rest both on quantitative and qualitative methods, the urge being to overcome the limitations of both. Does not Faust's exclamation in Goethe's famous tragedy—"*Verweile doch—du bist so schön...*" (Tarry awhile—thou art so beautiful)—suggest that the principle of indeterminacy operates not only in the microcosm? After all, the closer we probe the quantitative aspect of phenomena, the more we find their qualitative aspect tending to escape us. Indeed, the logical (that is, ultimately qualitative) nature of the initial postulates of mathematics was emphasised more than a century ago by Frederick Engels in his *Dialectics of Nature*. [1]

At any rate, nowadays it is not only in the social but also in the natural sciences that the limitations of mathematicisation in the narrowly quantitative sense are being broadly recognised. John R. Platt said: "I think ... that much of the mathematicising in physics and chemistry today is irrelevant if not misleading.... We substitute correlations for causal studies.... Many—perhaps most—of the great issues of science are qualitative, not quantitative, even in physics and chemistry. Equations and measurements are useful when and only when they are related to proof; but proof or disproof comes first and is in fact strongest when it is absolutely convincing without any quantitative measurement.... The mathematical box is a beautiful way of wrapping up a problem, but it will not hold the phenomena unless they have been caught in a logical box to begin with." [2] Accordingly, it would apparently be better to speak of mathematical rather than of quantitative methods in the science of science, taking this in the broad sense, in the sense of the unity of logic and mathematics, of qualitative and quantitative analysis, and not of their antithesis.

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[1] Frederick Engels, *Dialectics of Nature*, Moscow, 1974, p. 257.

[2] *Science*, Vol. 146, No. 3642, October 16, 1964, pp. 351-52.

For all its imperfections, the developing statistics of science makes it possible little by little to analyse some quantitative parameters in the growth of scientific activity, and to use them as a basis for formulating simple methods and bringing out the tendencies of future development. This accords with the very logic of scientific cognition as an ascent from the abstract to the concrete, and from the simple to the complex; an evidence of this will be found, for instance, in the growing "mathematicisation" of science. In the study of science, as a social institution, natural-science models making use of analogies of physics, chemistry and biology are used alongside mathematico-statistical methods. Thus, W. V. Smith, manager of the physics group at International Business Machines Corp., says that "phase transitions and cooperative phenomena in solid state science have analogies in management". [1] Lawton M. Hartman derives his model of the growth of scientific knowledge from a simple analogy with reaction processes in a gas. The information gain depends on the amount of information already available. Hartman visualises a "gas" whose molecules are scientists and pieces of information. The scientist molecules do not move significantly, whereas the information molecules move with an assumed constant velocity in random directions. A useful reaction (the generation of new information) is supposed to occur when the scientist molecules have "reaction cross section" on being hit by the information molecules. Lenz uses a biological model for technological forecasting—an analogy to biological population growth under constraint. [2]

I think that materialist dialectics has the best chance of becoming the universal method in the science of science, after it has been invested with the necessary strictness. On that basis systems analysis is the most adequate to the information nature of scientific activity as an intricate open-ended dynamic system. The language of systems analysis makes it possible to describe simple and complex, discrete and continuous, determined and probability processes in scientific activity itself and in its

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[1] *Science*, Vol. 167, No. 3920, February 13, 1970, pp. 957-59.
[2] Erich Jantsch, *Technological Forecasting in Perspective*, OECD, 1967, pp. 148-55.

conditions, mobilising and assimilating whenever necessary the ancillary languages of the particular (special) methods. The facility of such assimilation can now serve as an indicator of the applicability of mathematical methods in each special case.

In this context, the greatest advantage appears to exist for the organisational methods of the science of science which accord with the organisational conditions of scientific activity and which rest directly on the achievements of structural analysis, the theory of systems and cybernetics. In this case, the assimilation is the most organic, and the sphere within which mathematical methods may be applied, the most extensive. This includes, for instance, the study of the dynamics of the scientific activity system on the macro- and microlevels, the systems analysis of the network of research establishments and centres, the optimisation of the structure and size of research teams, and so on. Let me add that tangible results derive in most cases from the use of sociological polls (questionnaires, interviews), provided the data obtained are sufficiently representative and compatible. The selection and analysis of the latter is perhaps the most difficult task in processing the data of sociological polls after these have been run through the electronic computer.

The sphere of organisational conditions and methods of scientific activity is much more comprehensive. Indeed, the sphere of economic conditions and methods is included in it as a specific instance of the organisation and administration of science with the use of value instruments, which become truly meaningful only at the final stages of research, where the correlation between costs and results becomes definite enough for economic analysis. Indeed, it is here, in applied R & D, that modern mathematico-economic methods for studying micro- and macrolevel of research are applied. The more intricate methods of framing and control of R & D estimates are based on an analysis of operations, with a division into stages (steps) and the use of machine modelling.

The use of these methods on the microlevel yields a tangible effect, but one should be warned against any hasty extrapolations of such methods onto the macrolevel of research, where much more intricate dependencies tend to operate, especially in the socialist countries.

But contrary to the accepted view, this does not mean that there can be no single criterion of the efficiency of inputs into scientific activity. There is such a criterion, and it was first brought out by Marx, when he wrote: "The development of fixed capital is an indication of the extent to which social knowledge (Wissen) in general has become a *productive force in its own right,* and from there, an indication of the extent to which the conditions of the social vital process itself are subject to control by the universal intellect and are transformed in accordance with it; the extent to which the social productive forces have been created not only in the form of knowledge but also as immediate organs of social practice, of the real vital process." [1] In 1974, more than 83 per cent of the growth in industrial production came from the growth of labour productivity. [2]

The qualitative change in fixed assets has been proceeding at a growing pace. From 1961 to 1965, the production of 1,900 obsolete machines, equipment, apparatuses and instruments in Soviet engineering was discontinued; from 1966 to 1970, the figure rose to 2,500, and from 1971 to 1974, to 5,800. [3] On the other hand, from 1966 to 1970, 21,300 models of new types of machinery and equipment, apparatuses and instruments were engineered and their batch production started, and from 1971 to 1974—15,900. From 1966 to 1970, an average of 135,000 production equipment units were modernised every year, and from 1971 to 1974—153,000. From 1965 to 1975, the number of mechanised flow and automated lines nearly trebled, coming to 114,108 and 17,072, respectively. [4] In the Soviet period, the power available per worker in industry multiplied 33-fold, and the electric power facilities, 53-fold. [5]

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[1] Karl Marx, *Grundrisse der Kritik der politischen Ökonomie (Rohentwurf) 1857-1858,* Berlin, 1974, S. 594.

[2] *The USSR in Figures in 1974,* Moscow, 1975, p. 36 (in Russian).

[3] *The Economy of the USSR. 1922-1972,* Moscow, 1973, p. 73 (in Russian).

[4] *The Economy of the USSR in 1973,* Moscow, 1974, pp. 185-87; *The USSR in Figures in 1974,* Moscow, 1975, p. 75; *The Economy of the USSR in 1975,* p. 173 (in Russian).

[5] *The Economy of the USSR in 1975,* p. 174.

The development of fixed capital is the criterion which makes it possible to determine *not only the economic but also the social effect* of scientific activity, which acquires especial importance at the macrolevel. The report given at the 25th Congress of the CPSU by Chairman of the USSR Council of Ministers A. N. Kosygin urged the need for all-round intensification of production, acceleration of scientific and technical progress and boosting of labour productivity as the crucial factors in raising the efficiency of production and the people's living standards.

The social effect is measured by the extent to which the conditions of life in society have been rationalised and subordinated to "control by the universal intellect". This includes, among other things, the development of scientific forecasting of society's requirements and resources, the planning of production and distribution, optimisation of consumption, and so on. In other words, it includes the transformation of social production into scientific and scientifically managed production. This criterion may well be taken as the basis for the use of particular methods of sociological analysis with the systems approach to the study of the social conditions of scientific activity, methods which already involve the extensive use of mathematical formalism (polls of scientific groups, processing of data on science statistics, education, and so on).

Mathematical (if not quantitative) methods of systems analysis are also applicable in studying the logical structure of scientific knowledge, the regularities underlying the succession of scientific conceptions, and so on.

Quantitative methods themselves are used to some extent in studies of the history of science and technology, involving historical statistics, machine methods of classifying and analysing historical information, and so on.

From the standpoint of the use of quantitative methods, a peculiar set of demands spring from the psychological analysis of scientific endeavour, involving a "black box" like the researcher's creative laboratory. Here, the greatest acceptance has been given to the method of expert evaluations (Delphi, and so on).

Consequently, there should be no underestimation (or overestimation either) of the applicability of mathematical methods in general, and of quantitative methods in particular, in the science policy. This refers both to the subject-matter and to the general method of the science of science, and especially to its particular methods. Even a cursory analysis shows a fairly well-defined area beyond which the use of strictly quantitative and even of mathematical methods in general tends to yield problematic results. Thus, an analysis of quotation grids on the basis of quotation indexes yields a definite effect in bringing out interest communities in science (so-called "invisible groups"), in establishing the intensiveness of interscience ties, and so on. But this method clearly cannot claim to be the main one, to say nothing of being the only way of measuring the individual creative productivity of scientists. [1]

From mathematical formalism the study of the organisation and management of scientific activity inevitably moves to the formalism of metamathematics.

The actual contradictions inherent in the development of science as a system of knowledge, which is both finite at every given moment and infinite as a process of cognition, have inevitably brought about a search for ways to overcome these. The earliest attempts amounted to a search for some "absolute" and perfect system of knowledge which was free from contradictions. Such attempts have been enshrined in all kinds of classifications of the sciences which were most assiduously produced in the course of the past two centuries. [2] The futility of such attempts was fully brought out in the 20th century, as the succession of new classifications became obsolete without having been actually adopted in scientific use. As a result, the orientation of the search changed. Instead of seeking a complete, that is, static and, consequently, un-

[1] Every researcher knows that the real conditions for the publication of scientific results are of themselves not always of a scientific character. This applies to an even greater extent to the ethics of scientific references.

[2] See, B. M. Kedrov, *Classification of Sciences,* Vol. I, Moscow, 1960; Vol. II, Moscow, 1965 (in Russian).

real system of knowledge, this quest was oriented upon a discovery of some mechanism adequately reflecting the real contradictions in the process of cognition and developing along with it. It was mathematics, which in the same period also came to realise the need for self-cognition, that provided science with such a mechanism as it turned to the study of the laws of its own development. One of the three maxims inscribed on the Temple of Apollo at Delphi was "Know thyself", and two-and-a-half thousand years later it has suddenly been realised as the categorical imperative in the further progress of science and its mathematical language.

The required mechanism was provided by metamathematics, above all the theory of sets and the theory of systems which is based on it. Y. Vasilyev, writing on the 60th anniversary of the outstanding Soviet mathematician A. A. Lyapunov, said: "In the theory of sets, mathematical methods are used to analyse mathematics as a whole, its basic conceptions and the fundamental questions of structuring the whole of mathematics on that basis.... One could say, in a manner of speaking, that just as man comes to realise the need for self-control and self-possession, so at one point mathematics attained to the theory of sets." The mathematics of mathematics provides a natural language for the science of science.

Structure, describing the stratification of infinity into hierarchical levels to the extent to which the latter is covered by the theory of sets, was one of the most fruitful conceptions for the theory of the development of science, and especially for the theory of its organisation. N. N. Luzin, A. A. Lyapunov and other Soviet mathematicians have made a crucial contribution to the study of the structural properties of sets and the processes of their interrelated constructions.

Every organisational structure consists of hierarchical levels. When one considers the structural levels of science policy, one will easily find that all the elements of the microlevel (research and design institutes, development offices, their sectors, departments and laboratories) are also elements of the metalevel, its subsystems (or subsets, to use the language of Boolean algebra and the theory of sets). For their part, all the elements of the metalevel (science centres, comprehensive R & D pro-

grammes, intersectoral problem projects, associations, firms) are part of a subsystem (subset) of the macrolevel of state science policy. None of these subsystems can be understood or described outside the context of the system (set) to which it has to be amplified. The microlevel of science organisation has to be analysed by being amplified to the metalevel of the scientific network, and the latter, to the macrolevel of science policy. This follows from the basic theorems of the theory of sets and metamathematics. [1]

"There is a statement A in Z_1 such that neither A nor $\sim A$ can be proved from the axioms of Z_1", [2] or "Every W—consistent and adequate arithmetical logic is incomplete," says Gödel's famous Incompleteness Theorem. [3] Let us note that the physical meaning of this theorem is identical to Einstein's relativity principle, according to which all the laws of physics are similar within systems in rectilinear and uniform movement with respect to each other. That is why an observer located in one system cannot discover the movement of this system by means of observations confined within the limits of that system. The full physical meaning of Gödel's Incompleteness Theorem is to be found in Niels Bohr's Principle of Complementarity, with its exceptionally extensive application. [4]

From the complementarity principle and Gödel's Incompleteness Theorem follows the *external complement principle,* which was formulated by the well-known cyberneticist Stafford Beer, and which says that no system can be understood or described within its own framework.

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[1] See, Robert R. Stoll, *Sets, Logic, and Axiomatic Theories,* San Francisco and London, 1961.

[2] Paul J. Cohen, *Set Theory and the Continuum Hypothesis,* New York, 1966, p. 39.

[3] Formal logic says that in a correct syllogism at least one of the premises has to be a general affirmation or general negation, as otherwise the conclusion will not be valid or at any rate will have no claim to be a generalisation: only a particular conclusion follows from particular premises. In other words, to obtain a positive general solution of a problem, one has to go beyond the framework of particularities when it is just being formulated.

[4] Niels Bohr, *Atomic Physics and Human Knowledge,* New York, 1958, p. 99.

To do so, one needs to go beyond the framework of the given system A, and to complement it with a system of a higher order. Or, in other words, the inadequacy of any lower-order system can be overcome by transition to a higher-order system (metasystem) describing the former and making it possible to overcome the contradictions which are insoluble within its framework. That such transition is possible in principle is shown by Gödel's Completeness Theorem, which says: "Let S be any consistent set of statements. Then there exists a model for S whose cardinality does not exceed the cardinality of the number of statements in S if S is infinite, and is countable if S is finite." [1]

Let us note that the theory of sets itself with its theorems and the external complement principle based on these relates to all the other departments of mathematics as to its own subsystems (subsets). Hence, the profoundly fundamental character of the external complement principle and the unlimited sphere of its operation covering the regularities not only of nature, but also of society. Indeed, practical technical need tends to propel science forward much more than a dozen universities, and this is well borne out today by the experience of "Big Science". The reason is that the requirements of practice operate as an external complement to the theoretical potential of scientific knowledge. This is effected not in a static state but in a dynamic process. As human knowledge is extended and deepened, the external element is increasingly converted into an internal one, only to be reconverted into an external element on a higher level, so inaugurating a new cycle. History shows that it is through the external complement, through transition to a higher-order system of control that mankind has coped with its problems, switching these from the external plane to the internal, and from there back to the external.

One could say that men have instinctively used the external complement principle long before it was formulated in cybernetics. For the purpose of resolving conflicts, they set up courts of justice, providing society with

[1] Paul J. Cohen, *Set Theory and the Continuum Hypothesis*, p. 13.

an apparatus for overcoming the contradictions among its members. Meanwhile, the resolution of higher-order conflicts was handled by the state which, like the courts, was an instrument of control in the hands of the ruling classes. Finally, the resolution of disputes among states was handled by international law, including the "law of war and peace". But even then all of this proved to be inadequate, and so another "supersystem"—the Church—was set up. But the Church proved to be incapable of resolving the conflicts arising from social development. Its foundation was eroded by ideological and social revolutions, and the chief religions, of the world of themselves split up into a great many smaller churches.

Today, in this age of the scientific and technical revolution, there is the widespread view that science tends to assume the functions of the supreme metasystem. As the outstanding Soviet scientist, Academician V. I. Vernadsky put it, neither world religion nor philosophy was able to cope with the problems facing mankind. "Scientific thought—common to all—and also scientific methods, which are common to all, have now gripped the whole of mankind, spreading across the whole biosphere, transforming it into a noosphere.

"This is a new phenomenon which invests with special significance the current growth of science, the explosion of scientific creativity." [1]

While the great geographical discoveries enlarged mankind's terrestrial horizons, giving it a broader and more amplified conception of its planet, the great cosmic discoveries give it a tangible sense of the great immensity of the universe and the actual place of the "planet of men" within it. Let us bear in mind that space exploration became necessary and possible at the point at which the globe turned out to be too small for the energy capacities and flight speeds achieved by men. The Soviet and US space programmes helped to raise to a higher stage not only international law (within which space law has developed as a branch in its own right), but also contemporary political thinking.

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[1] V. I. Vernadsky, *Scientific Thought as a Planetary Phenomenon* (Scientific Legacy), Archives of the USSR Academy of Sciences (in Russian).

Consequently, whatever the circumstances we should not lose sight of the general and overall direction of development which provides the solution of the fundamental problems of science policy on the external complement principle. Lenin said: "Anybody who tackles the particular problems without having previously settled the general ones, will inevitably and at every step 'come up against' these general problems without himself realising it. To come up against them blindly in every individual case means to doom one's policies to the worst vacillation and lack of principle." [1] With an eye to this rule, the inadequacy of any lower-order system in science policy can be overcome through transition to a higher-order control system (metasystem).

In other words, the contradictions which are insoluble within the framework of the given system can, in principle, be solved within the framework of a larger system describing the given one. The inadequacies of the language for a complete description of the system are overcome by moving to a metalanguage corresponding to the metasystem. The external complement principle, which implies that any actual (but not artificial) contradictions can ultimately be solved, may well be called the principle of optimism.

However, there is usually a considerable gap between the possibility of resolving contradictions (problems) in principle and their actual solution. The potentiality has yet to be converted into reality, and the external complement principle would not be true to itself if it ignored its own requirement of sober consideration of the real contradictions.

That is why full account is taken in cybernetics of the fact that the transfer of any problem from the framework of a given system to the broader framework of a metasystem can be effected only at the price of introducing indefiniteness or, to be more precise, through the inclusion of a "black box" [2] in the complementary chain of external control.

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[1] V. I. Lenin, "The Attitude Towards Bourgeois Parties", *Collected Works,* Vol. 12, p. 489.

[2] To understand how the "black box" works in solving problems on the external complement principle, let us consider

The limits of mathematical (and not only quantitative) language and the possibilities of overcoming these with the aid of metamathematical language stand out as one moves to an analysis of science as an object (and also as a subject) of control in the strategy of the scientific and technical revolution. Let us start this analysis with the primary basis of scientific activity, with the man of science and his relationships with the scientific organisation.

Zeno of Elea's well-known aporia about the liar: "The Cretan X says that all Cretans are liars. Is X telling the truth?" This aporia is resolved by means of the following enlargement of the framework of the problem through indefiniteness: Cretans, *like all men*, occasionally tell the truth, and occasionally do not. "All men" here are the metasystem with respect to "Cretans", and "occasionally" is the "black box" because of its indefiniteness (for we do not know when, "on what occasion", the Cretan X spoke). But in any case the transition to the metasystem enables us not to accept X's claims that his assertions are categorical and universal: after all, X is also human, and so is subject to all the vagaries of human nature (see, A. O. Makovelsky, *A History of Logic*, Moscow, 1967, p. 62, in Russian).

Chapter Two

Man and Science Organisation

However epoch-making the advances in the development of the various elements of the productive forces, their formation into a system is of ever growing importance. The interrelations between men involved in the social production of material and spiritual values, the instruments of their labour and the forces of nature they use tend increasingly to stand out. Today, science and the organisation of social labour and production have a considerable role to play in the development of the productive forces system.

Science has acquired unprecedented scope, having become one of the key and major spheres of social life and activity, and this is expressed in the marked increase in the absolute and relative importance of the inputs going into R & D all over the world. According to a UNESCO estimate, world R & D inputs add up to a total which is close to the size of the national income of a country like Britain. Since the turn of the century, these inputs have increased at least 50-fold; the share of R & D inputs in the Gross National Product of the industrial countries comes to between 1.6 and 3 per cent. [1]

Another indicator is the growth in the absolute and relative numbers of scientific personnel. Already, the number of scientific personnel tends to approximate the population of, say, Norway. There is one researcher per 1,000 population of the globe.

But in the present conditions, researchers cannot do without ancillary and service personnel, who are, on

[1] *Science Indicators 1972. Report of the National Science Board 1973,* Washington, 1973, p. 4.

average, two or three times more numerous than researchers.[1] Today, there are close to 16 million men and women all over the world who are engaged in science and the provision of scientific services.

The growing scale of scientific activity, together with the complexification of the tasks before it, has determined the development of its organisational structure. The "Small Science" of solitary scientists with their few laboratories and academic departments has been transformed into the "Big Science" of large scientific groups with a high level of organisation.

For its part, the development of organisation, above all the organisation of social labour and production, is increasingly determined by the development of scientific activity. The extent and intensity of this influence is directly proportional to the extent to which science becomes the leading element of the productive forces and to which the social function of science has grown. While the influence of science on society's development tends to increase as it becomes ever more organised, the influence of organisation on society is increased as it acquires scientific character. As a result of the growing interpenetration of science and organisation, in socialist society the two tend to coalesce into scientific organisation in the broad and the narrow sense of the word: the scientific organisation of society, and the scientific organisation of science itself. Only highly organised science in the full sense of the word can be a productive force of modern society. And only the scientific organisation of social labour and production is capable of raising its efficiency to the level of the demands of the scientific and technical revolution and the tasks of communist construction.

The synthesis of science and organisation, the development of scientific organisation in the broad and narrow sense of the word introduce fundamental changes into the state of the productive forces (and, consequently, of social relations as well). Scientific organisation, as a synthesis of science and organisation, increasingly operates as the guiding pivot of the productive forces of society as a whole. The coalescence of science and organi-

[1] I. A. Maizel, *The Sociology of Science: Problems and Prospects*, Leningrad, 1974, pp. 3-4 (in Russian).

sation and of organisation and science is the highroad of the current scientific and technical revolution. It is safe to say, therefore, that it is the development of organised science and the scientific organisation of social labour that help to transform the aggregated elements of society's productive forces into an actual system.

The most striking confirmation of this comes from the diverse and deep-going contradictions between scientific and technical and socio-political development in the second half of the 20th century. The bond linking up the elements of the productive forces system increasingly appears to be imperative and inevitable. The one-sided and separate development of any of these elements inevitably results in grave and frequently intractable disruptions of equilibrium within the system. The uneven and contradictory development of the productive forces system in definite conditions is a reflection, above all, of the impact exerted by obsolete relations of production. Only the triumph of progressive social relations all over the world will open up real prospects for the harmonious development of the productive forces system on the basis of self-regulation and self-organisation.

But even today, the social character of the productive forces proclaims itself at every level of organisation and control from the primary group to the country as a whole. There is also need for the systems approach in tackling the problems arising between man and the organisation in the process of production and the application of scientific knowledge and technical skills.

Homeostasis of Organisation and Nonconformism of Scientists

Let us now consider the nature of work in science. What are its specific features?

In science, work tends organically to be cooperative and collective. The very word "scientist" implies that he is a person who has been trained and who has assimilated the scientific knowledge created by his predecessors and contemporaries, notably, in his special field. No scientific discovery has ever been made in a vacuum; it was Newton who said that he stood on the shoulders of giants. In this age of unprecedented pace and scale in scientific

activity, the cooperative character of scientific work is even more evident. Being essentially immediate social labour, scientific work in the 20th century is, in addition, joint work, which means that it entails direct cooperation among individuals.

The development of scientific knowledge requires "testimonials", that is, the right to refer to the procedures, postulates and premises which are common to the whole scientific community. These testimonials make society accept the results of the individual's work as a legitimate product of scientific activity, thereby socialising these results in a depersonified form, which is stripped of all subjective characteristics.

Social recognition of scientific achievements is vested above all in scientific groups. Like all immediate social or joint labour effected on a relatively large scale, the work of the numerous scientific groups in our day requires "more or less, a directing authority, in order to secure the harmonious working of the individual activities, and to perform the general functions that have their origin in the action of the combined organism, as distinguished from the action of its separate organs. A single violin player is his own conductor; an orchestra requires a separate one." [1] In the second half of the 20th century, science is inconceivable without specific organisation and control, and this is felt by every scientist, even if he works alone. [2]

However, from these specific features of contemporary scientific work it follows that the scientist, but recently having the status of a "liberal artist", is being converted by the force of circumstances into an "organisation man". Of course, the nature of the social system leaves an imprint on the forms and tendencies in this transformation, but many complicated socio-psychological problems in any case tend to arise.

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[1] Karl Marx, *Capital,* Vol. I, Moscow, 1974, p. 313.

[2] Very often, the growing collectiveness of scientific work is illustrated by the growing number and share of works with two, three and more authors. At the same time, there has been a marked reduction in the number of disputes over priority to discoveries and inventions simultaneously made by different scientists.

The point is that the synthesis of science and organisation considered above is realised through a multistage and sufficiently intricate development. The organisation form is far from being a neutral element with respect to the content of scientific activity and the requirements of its development. The organisation integument was set up in order to fence this activity off from unfavourable external impacts. For centuries, organisation has fairly successfully fulfilled this function, as one will realise by recalling the role of the academic freedoms and "university autonomy" which in varying extent safeguarded scientists from interference by the authorities, the Church, and so on.

It is true, of course, that the independence of scientific organisations was fairly relative, for the academic privileges were themselves frequently up for sale. Thus, according to an apt remark by Chamfort, the French Academy survived by doling out its privileges. The same applies to other countries, where influential grandees were elected honorary members and even presidents of academies.

The protective functions of scientific organisations were confined to the framework of the accepted legal order established by the ruling classes. Whenever a university came out in defence of some "heresy", the authorities instantly forgot about "university autonomy", and then it was no longer the development of science but the university's very survival that had to be defended. Thus, the scientific societies set up in North America largely to spite the universities and colleges frequently sought to acquire the status of academies (even if only on the scale of their state).

The US philosopher Barrows Dunham remarked that science requires some things which only organisations could supply: thousands of trained observers working together, and a vast technology of experiment. But it also requires an eagerness for new information, and a willingness to revise or discard inherited doctrines as these prove erroneous. If survival is the aim of every organisation, if unity and devotion in the membership are necessary to that survival, and if a certain description of the world is essential to that unity, then what is chiefly required of the description will not be correspon-

dence with fact but persuasiveness to the membership. "Therefore if ... orthodoxy is what the leadership defends, science must tend to be always and everywhere heretical." [1]

Every organisation, in virtue of its functions, tends to be oriented upon stability, upon the conservation of the state of things to which it has been adapted. That is why it requires of its members, including scientists, that they should not transcend the framework of the established principles, rules and notions. In other words, conformism has been regarded from time immemorial as the prime virtue of the membership of any organisation.

Even in this 20th century, conformism is not a rare visitor, but master in many scientific organisations. When new personnel are taken on by the major private industrial scientific organisations in the United States, preference goes to the complaisant person capable of working with his colleagues, rather than those who have greater scientific capability but are unable or unwilling to collaborate. This kind of approach to the selection of personnel will merely intensify the conformism, whose growth is already pronounced in organisations which exist in complicated conditions.

Let us note that in scientific organisations conformism frequently exists side by side with tolerance of all kinds of mavericks. The well-known US sociologist Norman Kaplan believes this kind of tolerance is a necessary condition for creative scientific activity in organisation. [2] What is more, some US corporations have paid large salaries to highly imaginative mavericks as generators of ideas (so-called "will birds"). But this exception, allowed for a few outstanding nonconformists, merely goes to confirm the general rule which has sufficiently deep socio-political roots. Conformism for the crowd and nonconformism (independence) for the elect few help to advance towards the same goal, which is to keep the existing organisation solid.

Tolerance of nonconformists is that instrument by means of which the organisation adapts itself to the

[1] Barrows Dunham, *Heroes & Heretics. A Political History of Western Thought,* New York, 1964, pp. 304, 305.

[2] *Science and Society,* Ed. by N. Kaplan, Chicago, 1965, p. 219.

changing situation (within certain limits). "Such graces ... as tolerance ... belong to periods of stability, when the organisation is under no great stress. They begin to disappear as the organisation begins to be embattled, and perhaps vanish altogether if the organisation fears for its life." [1]

Meanwhile, research is essentially hardly compatible with conformism. Ready-made knowledge, which usually appears as the result or condition of research, is frequently questioned and modified. The Swedish philosopher Håkan Törnebohm emphasises that it is these "discrepancies" in the operation of the scientific system that frequently produce major discoveries (like those of Einstein and Bohr). He adds: "The little grains of sand are a great worry to the oysters, but they help to originate the pearls." [2] The conformist mentality, says the Soviet sociologist I. Kon, is antithetical to the scientific approach. In the sphere of the cognitive functions, he adds, the conformists reveal a less developed intellect than the independents; they have a characteristic inflexibility of thought and poverty of ideas. [3]

The conflict between conformism and nonconformism is not the only contradiction in the way of the synthesis of science and organisation. There are other problems which arise at every stage of the work, from the generation of ideas and the selection of projects to their complete realisation or termination. The nature of these problems is largely determined by internal factors like the division of the collective into formal and nonformal small groups, their make-up, age, and the personalities of their leaders and managers, and so on. Thus, under the impact of these factors conformism may grow from an unconditional acceptance of the acts of the management into an equally unconditional acceptance of the approach taken by an influential nonformal leader of a small group which is directed against the management. This, of course, implies that such a leader himself is a nonconformist.

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[1] Barrows Dunham, op. cit., p. 229.

[2] H. Törnebohm, "Badania zunifikowane", *Zagadnienia naukoznawstwa*, Warsaw, 1973, Vol. 9, Part 2, p. 178.

[3] I. S. Kon, *The Sociology of the Individual*, Moscow, 1967, pp. 89, 92 (in Russian).

All of this can be palpably influenced by powerful even if temporary factors. Thus, in stress situations (for instance, the frequent need for extremely intense effort to complete a difficult job by a fixed deadline), conformism may have a positive role to play not only in a production but also in a scientific group. Subordination of everyone to the will of the organisation, as personified by the director, not only helps to bring the project to success, but also to enhance the capabilities of the group in general. As a research collective acquires greater cohesion, there is an enlargement of the reference group, whose opinion cannot be ignored. This affects every researcher individually and all of them together. The enlargement of the reference group may go well beyond the framework of the given organisation ("invisible colleges"). The interdisciplinary character of many projects also carries beyond the framework of the specialty and profession.

The contradictions of scientific organisation are determined by the circumstances in which science and organisation are synthesised. As scientific activity becomes one of the most massive professions, it involves millions of men and women, only a handful of whom have outstanding creative abilities. A few leading researchers continue to generate the essential and the most valuable part of the scientific product. [1] Meanwhile, scientific activity continues to be (primarily because of these scientists) essentially creative, and scientific discoveries to be the most highly valuable accomplishments of any person involved. It is not surprising, therefore, that virtually every new recruit to "Big Science" today carries the field marshal's baton in his knapsack (or at any rate, believes he does). There is a serious danger that scientific activity may come to be a vogue and so degenerate. Only scientific organisation with a clear-cut division of labour within the team is capable of employing every participant in research in accordance with his abilities. But the price it exacts for this is some degree of conformism, which in definite social conditions is opposed to the creative approach.

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[1] *The Science of Science*, Moscow, 1966, p. 322 (in Russian).

The process has come full circle. However, science does not stop, because reality breaks through the circle, inducing the organisation and the creative individual to display mutual tolerance. According to the Polish sociologist Matejko, "the processes going on within the creative collective are characterised by a dialectical struggle between two opposite trends. One of these is aimed to achieve the maximum of internal cohesion within the collective as a definite social group (requiring more or less conformism of its members), and the other postulates creativity and is aimed against stagnation, which threatens cohesion with degeneration to rigidity.

"The collective operating within the framework of a definite organisation, abiding by its rules and realising its purposes, as agreed with the higher authorities, has an ever higher standing in science. Meanwhile, creativity, now and in the future, is a phenomenon relating primarily to concrete individuals, a phenomenon requiring individual freedom and one which is anti-conformist by definition. That is why there is the very meaningful task of coordinating the requirements of creativity with the requirements of rational organisation, on the one hand, and of the individual's creative freedom with the principles of collective cooperation, on the other." [1]

Consequently, the task is to find the parameters of a dynamic equilibrium for scientific organisation, under which a sufficient number of the degrees of freedom for generating and elaborating new ideas would be balanced out by sufficient stability of organisation. This kind of equilibrium continues to be imperative so long as the organisation serves as a necessary protective integument for research.

In his fundamental work, *The Social Function of Science*, which was published in 1939, J. D. Bernal observed that men's lives would be immensely improved by duly organised science. But the point is to organise it in such a way as to enable the scientists to work with the greatest efficiency and society to derive the maximum benefit from their activity. One of the main problems was to reconcile the need of organisation and the individual

[1] A. Matejko, *Conditions for Creative Work*, Moscow, 1970, p. 6 (in Russian).

freedom of the scientist. What Bernal had in mind was not so much the problem of control as the reorganisation of a whole apparatus of scientific communication, which in science has the same role to play as management has in other spheres of social life. Scientific integration is achieved, on the one hand, by means of rational organisation, and on the other, by means of an efficient information service. [1]

In the past few years, concrete social studies have brought out some of the reference points in the solution of this problem.

Extensive studies of the behaviour of scientists in organisations have been made in the USA for the purpose of improving the effectiveness of research and development, and have yielded valuable observations for comparative analysis.

The well-known firm of consultants, Arthur D. Little, Inc., in a study for the Director of Defence Research and Engineering at the Pentagon, investigated six representative weapon system out of 87 contributing "research and exploratory development events". [2] It established that of the greatest importance for the success of this work were: clearly formulated requirements; the availability of resources which could be used at once (a delay of even one or two months, it was established, had a cooling effect, with the men no longer generating ideas, and a six-month delay had terrible consequences); and an experienced group.

A clearly formulated requirement is nothing but the *objective* of the organisation. The existence of a clear-cut objective, of one that has been recorded in written form, is the first indication of competent leadership. A fixed objective is the starting point for normative forecasting and planning, without which no scientific organisation can exist or develop under the current scientific and technical revolution. At the same time, a clear-cut objective serves, like nothing else, to knit the creative group together, uniting the organisation and balancing out conformism and nonconformism (naturally, unless the latter encroaches

[1] J. D. Bernal, *The Social Function of Science*, London, 1939, p. 292.

[2] Erich Jantsch, *Technological Forecasting in Perspective*, p. 74.

on the aim itself), that is, a clear-cut objective is an earnest of success for the organisation.

In this context, eloquent evidence comes from a study carried out in 1964 in a number of companies operating in the chemical and pharmaceutical, electronic, aerospace, plastics, petroleum, rubber, foods and feeds, metallurgical and manufacturing industries in the United States. It was established that 94 per cent of the companies polled practised the formulation of the objectives of their R & D projects; 79 per cent recorded these in writing, with the figure going up to 85.7 per cent for companies employing over 400 scientific and technical personnel, and dropping to 68 per cent for those employing from 1 to 25 persons.[1] The bigger organisations apparently had a more insistent need to record their objectives so as to muster the group of researchers and technicians for the purpose. The formulation of objective was directly connected with planning: 75 per cent of the companies framed special long-range R & D plans, and 77 per cent of these formalised their plans as written documents.[2] Almost one-half of the companies had plans for 5 or 6 years, but 80 per cent of the companies with large laboratories (employing over 400 persons) planned for periods of 5 to 10 years, and only 44 per cent of those with small labs (1-25 persons). The overwhelming majority of the companies (92.9 per cent) reviewed their R & D plans quarterly, semiannually, or once a year; only 1 per cent of the companies did this at intervals of longer than 1 year, and 6.1 per cent did so "as necessary".[3]

In R & D planning there is evidence of an urge to use formalised methods. By now, roughly one-half of the chemical companies studied by the Stanford Research Institute in Switzerland has long-range development plans (for 3 and more years). In Britain, such companies came to 75 per cent of the total studied, in the Netherlands to 60 per cent, and in Italy and Switzerland to 50 per cent. On average, more than one-half of the companies formulate special R & D plans, with 100 per cent in Italy, 80 per cent in the Netherlands, 67 per cent in France

[1] R. E. Seiler, *Improving the Effectiveness of Research and Development*, New York, 1965, pp. 51-52.
[2] Ibid., pp. 68-70.
[3] Ibid., pp. 71-72.

and 60 per cent in Switzerland. [1] There is a characteristic growth in the ever wider use of modern methods of scientific and technological forecasting, like the Delphic, morphological and the "goals tree" methods.

The procedures used in the formulation of objectives and planning have a direct bearing on the status of the researcher as an "organisation man". According to Seiler, 36.5 per cent of the companies required their research staff to submit time records monthly; 3.9 per cent biweekly; 49 per cent weekly, and 10.6 per cent daily. In other words, two-thirds of the companies exercise highly strict control, at least once a week. In these conditions, little is left of freedom of creativity, especially in the big laboratories (with more than 100 research staff) where time records are kept by 100 per cent of the companies as against 83.3 per cent for laboratories with up to 50 persons. [2]

This is largely due to the specifics of the industrial laboratories, 96 per cent of whose research staff are engaged in applied R & D projects, which lend themselves more easily to regulation. Thus, 68 per cent of the companies interviewed allow their research staff 10 and less per cent of free time (during the less busy part of the working day), and for only 32 per cent was the figure 10-20 and more per cent. It is not surprising, therefore, that only 60 per cent of new ideas came from the companies' research staff, and the other 40 per cent, from the marketing or sales staff (17.3 per cent), management (9.2 per cent), customers (4.1 per cent), government agencies (3.9 per cent) and other sources (5.5 per cent). [3]

This kind of practice naturally tends to reduce the efficiency of research staff. Thus, in 43 chemical companies of Western Europe the greatest number of *successful* research projects (31 per cent) was proposed by research staff, 23 per cent by R & D management, 12 per cent by marketing and sales department, and least of all (6 per cent) by customers. However, among the factors which influence the management's approval of projects com-

[1] J. Olin, "R & D Management Practices: Chemical Industry in Europe". In: *R & D Management,* Vol. 3, No. 3, Oxford, June 1973, p. 127.

[2] R. E. Seiler, op. cit., pp. 120-21.

[3] Ibid., pp. 132-33.

mercial and financial ones are the most important, and scientific factors the least important. [1]

Roughly one-half of the companies have a sizable projects backlog but just over one-quarter are capable of using 60 and more per cent of this. [2] This means that the second crucial condition for the successful operation of scientific organisation—availability of resources ready for immediate use (according to Arthur D. Little)—is being met in a minority of cases.

But the same appears to be true of the third condition—the existence of an experienced research group—which is closely bound up with the second. After all, such a group can hardly take shape when the organisation makes use of lesser part of the ideas generated by the research staff and especially when it does this with "disastrous" delays. There is an inevitable spread of disappointment among the research staff, and many tend to leave the group (which is made easier by the high mobility of personnel).

Consequently, only a minor part of scientific organisations in the USA, not only in industry, has all the conditions for successful work. Nevertheless, these conditions are available to a large section of US scientific personnel, because scientific activity in that country, while being broadly decentralised, is very highly concentrated at a few very high-level scientific organisations. Professor Harvey Brooks, a recognised theoretician of US science policy, has brought out the following distinctive features of the leading scientific organisations:

1. Full awareness and general acceptance of the principal goals of the organisation by its key people.

2. Willingness to consider and implement new ideas and initiatives on their own merits, regardless of the organisational level at which they originate, or whether they come from inside or outside the organisation.

3. Mobility of people between the more fundamental and applied activities of the organisation.

4. Quick recognition and funding of new ideas, at least to the point of ascertaining the desirability of a larger commitment.

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[1] J. Olin, op. cit., p. 131.

[2] R. E. Seiler, op. cit., pp. 136-37.

5. Extensive freedom at each organisational level in the organisation to reallocate the resources within its relevant area of responsibility.

6. Full communication through all stages of the research and development process from early research to ultimate user.

7. A good organisational memory for the enduring technological problems and themes related to the broad mission of the organisation or laboratory.

8. A system of recognition and reward that assigns highest significance to technical contributions to the goals of the organisation. [1]

Among these distinctive features of the successful research outfit one will easily discern those which are directly in line with the conditions formulated by the Arthur D. Little. But one should, besides, emphasise the priority given by these organisations to the earliest implementation of new ideas. This is ensured by keeping an open mind, allowing mobility of people, full communication, broad financial autonomy at every level, a good "organisational memory" and a flexible system of moral and material incentives. In other words, success comes to scientific organisations which function as open-ended systems, and which create the most favourable information and communication atmosphere for their research staff. The whole research staff from top to bottom is constantly kept informed about progress in the organisation, despite the danger of information leaks (say, to rivals). It is assumed that that is a lesser evil than the lack of information. With the exception of instructions and orders, information is usually spread along informal channels, outside of the official hierarchy.

The recommendations offered to future managers in a study aid at the Harvard School of Commerce have much in common with the different work rules adopted in various US organisations, which have been worked out in a purely empirical way. Thus, the largest industrial laboratory in the USA at Bell Telephone requires that scientists and research engineers taking on jobs should have the following qualities: knowledge, ability for self-

[1] Harvey Brooks, *The Government of Science*, Cambridge (Mass.), 1968, pp. 319-23.

education, an inquiring mind, a capacity for observation, a good memory and intellectual honesty, scepticism, imagination, enthusiasm and perseverance. On the other hand, in their relations with the staff, members of the management are advised to bear in mind that each needs to be encouraged for good work, wants to know about the prospects ahead, and doesn't like to be pushed around.

This approach is productive, as will be seen from statements by various scientists in the West who up until the end of 1960s regarded the favourable conditions for their work as being quite natural. They believed that various aspects of the scientist's professional ethics were about the only things that were worth discussing. A case in point is *Public Knowledge*, a book published by the US physicist J. M. Ziman in 1968, a large part of which consists of moralising on what the scientist has to do to be worthy of his calling. Ziman holds that the way to achieve identity of ideas is determined by the inner mechanisms of science, confining his field of vision to what is going forward at the work places and in scientific circles, and failing to realise that knowledge depends on social practice. [1]

But this practice gives reminders of itself.

Let us note that the excellent rules governing the treatment of scientists have not originated out of any Christian love for one's neighbour, but from purely pragmatic considerations. Ever since the time when science and education were first recognised as being factors in social production, Western economists began to consider inputs for these purposes as a new type of investment, investment in man. Only after man has become a recep-

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[1] J. M. Ziman, *Public Knowledge*, Cambridge, 1968.

Ziman starts from Kuhn's conception, according to which the development of science depends on the paradigms adopted in its concrete sphere. But while Kuhn considers the emergence of ever broader perspectives of knowledge, Ziman confines himself to observing the painstaking scientific quest within the given paradigm. That is why Ziman determines science as an urge to achieve identity of ideas based on a community of paradigm. The identity of ideas principle indicates scientific knowledge as the result of collective experience; before the scientist has formulated his problem he finds himself within the network of relations which link up his view with existing ones.

tacle of capital does the employer regard him as a "sacred vessel" that requires careful handling and a well-considered approach on the part of the managers. One veteran of many corporate mergers writes: "If you buy up another brain-factory here it is the scientists, primarily, that you are buying. You must be sure in advance that they won't feel like leaving you." [1]

Pragmatic concern for the condition of scientists and engineers in organisations has not only an economic but also a broader social implication. The creation of a normal atmosphere in the laboratories, an atmosphere of informal cooperation for the bulk of the research staff and a microclimate of tolerance for the "wild bird", helps to iron out the conflicts between routine business and scientific quest, between conformism and nonconformism.

Calvin W. Taylor, Professor of Psychology at the University of Utah in Salt Lake City, studied the atmosphere in many research and exploration development establishments (including US Air Force laboratories) for many years and discovered that it had not changed markedly, despite the numerous recommendations coming from psychologists. [2]

Taylor established that for the individual researcher advancement involves a growth of the "responsibility spectrum". A beginner is responsible for three or four types of activity, but at the higher levels he has to bear responsibility for 14-15 types. Being unable to concentrate, he loses his capability for creative work. Conversely, those who have such a capability have the least chance of making a career. Taylor calculated the number of applied new ideas coming from each member of the staff of a scientific laboratory and the effect this had on his career. It turned out that the two were in inverse proportion to each other. The greater the number of ap-

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[1] Christopher Rand, *Cambridge, USA. Hub of a New World,* New York, 1964, p. 25.

[2] Jack R. Gibb says that it is very hard to change a creative climate at an establishment for the better. Although theoretically everyone or almost everyone understands and accepts the psychologists' recommendations the manager finds it very hard to remould himself. No manager ever sets himself the aim of engaging in creative activity at the establishment in his charge.

plied new ideas, the slower was his movement on the way up. Taylor compared his results with those of other studies. A summer school for junior school teachers held tests for creative thinking and compared these with the teachers' official references. It turned out that those who had the highest marks in the tests had the worst references. A study of the personal files in one company showed that those whose activity had been of the greatest benefit to the company had once been close to dismissal; the management had planned to get rid of them frequently just before they made their valuable proposals.

The point, Taylor believes, is that in most organisations the leaders have their eye on the present instead of the future, which is why "the general finding is that the more highly creative idea a person has at any stage in his life, the more likely he is in trouble". [1]

New ideas frequently occur to rank-and-file workers, if only because they are more numerous than the managers. Meanwhile, only one in 20 of the interviewed lower-echelon managers was prepared to hear out his subordinates and try to understand a new idea (at the higher administrative level, the ratio was one to four). The system of recognition and reward is usually such that the manager prefers to let an idea go by rather than go to all the trouble involved in verification, for after all there is always the risk that the idea may prove to be a dud.

Usually, even the most progressive scientific establishment has a tendency gradually to become a "well-adjusted" and rigid mechanism acting as a brake on creativity. The ultimate evidence of creative stagnation usually comes in the form of an order from the director to elaborate "new scientific work rules and instructions". The triumph of bureaucratisation goes hand in hand with a freeze on creative initiative.

Taylor proposed the following mental experiment: scientists enumerate the measures which are required if creative initiative is to be completely stifled. The comparison of the list so obtained with the actual state of affairs in most laboratories shows that that is the actual

[1] *Climate for Creativity,* Report of the Seventh National Research Conference on Creativity, New York, 1972, p. 10.

day-to-day practice in scientific organisations. An attempt to find out how a given laboratory had still managed to come up with something new and original almost always showed that the initiative had come from someone outside the organisation. [1]

Gibb believes that the creative climate in organisations is determined by these four factors: latent fear and distrust, restricted flow of communication, attempted imposition of motivation, and attempted control of behaviour.

Where the management lives in fear of criticism, mistrusts and shuns new ideas, and is apprehensive of rank-and-file initiatives, the result is an atmosphere of nervousness and suspicion.

The distortion of the normal flow of information (frequently in the form of one direction flow of information) causes subordinates to conceal their ideas, "to retain them for oneself". Inventiveness is channelled into seeking ways of bending the rules, avoiding the goals of the organisation, and setting one's own goals instead. This is followed by a flourishing practice designed to put up a "bold front" and present a show-window effect; there arises a desire to appear calm and reasonable and to suppress any impulsive activity.

Where the attitude in the establishment is that motivation may be imposed on individuals from outside, that their own aspirations are inadequate, and that they have constantly to be persuaded about something, mostly with the aid of financial carrots, the result is stereotype thinking, indifference and an urge to go through the motions of working ("keep your mouth closed ... and make six copies of everything"). [2] Now and again, subordinates feel an inward resistance, but this is mostly expressed in rebellious behaviour and indiscipline, instead of productive accomplishments going to benefit the organisation as a whole.

The stricter and tougher the control over behaviour at the establishment, the more chances it has of inducing conformist behaviour among the staff, damping their thinking activity and extinguishing their creativity.

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[1] Ibid., pp. 1-22.
[2] Ibid., p. 26.

The leaders of such establishments usually act on the following assumption: subordinates respect only strict disciplinarians; rewards and recognition need to be very thoroughly distributed, because these are the main incentives; man needs to be constantly instructed, ceaselessly fed with rules of morality, while being urged to engage in creative thinking. Unless he is constantly prodded, he tends to become lazy, irresponsible, inclined to conformism, sluggishness and passiveness. All of this can be overcome only by a "strong leader". [1]

Past experience shows that under private enterprise the contradiction between science and organisation is relaxed in the biggest and most successful organisations (like the leading industrial corporations and their laboratories) in periods of economic boom. But once boom gives way to bust, the state of affairs undergoes a radical change even in the big outfits, to say nothing of the smaller ones. As appropriations are cut back, projects are cancelled and laboratories closed down. The reduction in investments for the purposes of combating the growing inflation also affects the personnel engaged in research, including scientists and engineers. The growing unemployment also has an effect on their conditions. In the 1970s, thousands of US scientists and engineers lost their jobs and were forced to cast about for work in other fields. The specialists who had been attracted to the United States by the favourable economic outlook and tantalising prospects in the 1950s and 1960s, began to return to Europe until it, too, was hit by the economic recession.

The growth of socio-political contradictions had an effect on the atmosphere in scientific organisations.

In the 1970s, the US Supreme Court ruled that the Federal Administration had the right to discharge government employees for criticising their superiors or for making public statements harmful to its activity. These developments had been forecast back in 1968 by OECD experts in a report on science policy in the USA. [2]

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[1] Julius J. Harwood, "The Changing Style of Research in the Business Enterprise". In: *Research Management*, Vol. 16, No. 5, New York, 1973.

[2] *OECD. Reviews of National Science Policy USA*, Paris, 1968.

A UNESCO report, entitled *Science and Human Needs*, says that bodies set up by scientists for the protection and advancement of their professional interests now make up a special group of scientific organisations. This function had earlier been exercised by scientific societies, but in the past few years the emergence of trade union and other associations of scientists is connected with the "proletarianisation of science", a process which is expressed, in particular, in the fact that scientists have ever fewer opportunities to influence the organisation of their work. It is increasingly obvious that these societies were unable to resist the growth of unemployment among scientific personnel and the worsening of their conditions. Personnel employed at scientific establishments and institutions of higher learning have been joining in the trade union movement ever more vigorously to stand up for their labour rights. [1]

The following data indicate a growth of trade union organisations. In 1966, only 5 institutions of higher learning in the USA had unions with a membership of 2,600 persons, but in 1973, 288 such establishments had unions with a membership of 80,000.

In 1973, the ratio of unionised to non-unionised among higher school teachers was 1 to 10, with only one in 6 full-time staff teachers unionised. The difference between the two figures is due to the fact that in countries with the biggest universities the share of staff teachers is much smaller. In 1973, roughly 12 per cent of academic establishments in the USA were unionised. Actually, some 40 per cent of all institutions were engaged in a form of faculty collective bargaining. [2] Unionism among persons engaged in scientific activity has also been spreading on this side of the Atlantic.

Gérard Vergnaud, Secretary-General of the National Syndicate of Scientific Researchers, France, wrote that the orientation of the National Centre for Scientific Research was extremely unfavourable for the scientists. The practice of strict selection of university laboratories and groups for cooperation with the Centre coincided with a slash in

[1] *Science and Human Needs*, UNESCO, Paris, 1974, p. 16.
[2] B. Aussieker and J. W. Garbarino, "Measuring Faculty Unionism: Quantity and Quality". In: *Industrial Relations*, Vol. 12, No. 2, Berkeley, May 1973, pp. 117-24.

university credits for research. Consequently, laboratories which fail to meet the National Centre's requirements run the risk of being left out in the cold.

The accent on limiting the terms of the "addition agreement" and also on a special examination procedure for Centre laboratories, which is repeated every five years, accords with the idea that the financing is limited to the period required to fulfil very definite tasks. The same purpose is pursued by the extension of "actions programmed by subject". According to Vergnaud, this contradicts the basic condition for the successful development of science, namely, the existence of permanent scientific groups.

The question of evaluating the effectiveness of research is a matter of paramount importance, but it should be borne in mind that if some scientific results are not immediately applied this occurs through no fault of the scientists but "of the private enterprises and the authorities in search of instant profits". [1] The Union of Scientific Research Workers believes there is a need to review the status of Centre personnel, and that only the status of government employees can provide Centre scientists with the guarantees to which they have a right.

Louis-Marie Chounet, Secretary of the Research Workers Section at the National Centre for Scientific Research, wrote that an analysis of Centre policy gave ground to determine it as "technocratic conformism". The attempts to introduce "objective methods of control over the efficiency of the work of scientists, automatic calculations of data for the advancement of technical personnel, and electronic computer analysis of publications" are likewise regarded as conformist. [2] Such practices, Chounet emphasises, could cause the democratic echelons of the National Centre to degenerate into technocratic echelons of control and decision-making.

Concerning the new status of the Centre, the Union put forward the demand that this status should be based "on a real analysis of the needs of research workers, and not on conformism towards the authorities". [3]

[1] "Où va le CNRS? La réponse des syndicats". In: *La Recherche*, Vol. 4, No. 34, 1973, pp. 501-02.
[2] Ibid., p. 503.
[3] Ibid.

Organisational Conditions for Scientific Productivity

What is the best way to blend organisation with the various creative capabilities of research staff and various research attitudes? Donald C. Pelz and Frank M. Andrews, two American scientists concerned with organisation, established that identity of mental attitudes, qualification, skills and experience helps to improve cooperation and coordination of efforts in a group, but could also result in a low productivity even if comfortable existence Conversely, differing colleagues face obstacles in cooperation, but can still stimulate each other to the solution of new and complicated problems. Productivity tends to increase with dissimilarities in style of approach to problems (abstract versus concrete, broad versus narrow, emphasis on instant versus long-term solutions, and so on). This is quite natural, because it is in line with the complementarity principle.

In contrast to research groups, technical development organisations were not found to have this kind of correlation. A positive effect was exerted on the productivity of development engineers only by dissimilarity in career orientation (scientific versus administrative). Meanwhile, the productivity of development engineers and scientists tended to increase, instead of declining, with the similarity of the sources of motivation (for instance, common enthusiasm in tackling a problem). Let us note that similarity or dissimilarity of motivation with the chief, in contrast to one's colleagues, did not show any marked influence on productivity.

Consequently, it may well be said that dissimilarity of motivation does more to promote the productivity of a scientific group than does similarity. It may also be assumed that the reason here is the growing diversity of the organisation as a system, and consequently, increase in the degrees of freedom in its activity.

This is also borne out by the data on correlation between the productivity of staff and the spectrum of their functions. An analysis of the effect on productivity of the distribution of time between scientific and organisational functions showed that productivity tended to grow in proportion to the share of the time allocated to

scientific work only up to the point where it took 75 per cent of the total working time budget and then tended to decline; among development engineers, this threshold lay at the level of 50 per cent. Consequently, in virtue of the same complementarity principle (external complement) the expenditure of a considerable portion of the time on organisational effort turns out to be beneficial for scientific productivity.

A similar correlation was discovered for the number of specialisation areas, whose increase from one to three resulted in an increase in scientific productivity from roughly 35 to 65 per cent. Productivity also tended to grow in proportion to the number of professional functions performed, but up to a certain point: where the number of such functions was more than four, productivity dropped more sharply in research laboratories, and less sharply in technical laboratories (while increasing among development engineers). It turned out that the optimal allocation of working time for research was between one-half and three-quarters, for development, from one-eighth to one-third (and for doctors of sciences in technical laboratories, up to one-half), and for the technical services (direct preparation of the experiment, records, and so on), about one-eighth. Among researchers working simultaneously on two or three projects, productivity on the whole turned out to be somewhat higher than it was among those working on one project (subject).

Of course, enthusiasm, the power of motivation is of great importance. The researcher's involvement springs from the interests generated by the content of the work itself rather than by its "importance". Whatever the source of the researcher's initiative—be it the scientist himself or his environment—the attitude of his chief and his colleagues to the project has a direct influence on his working mentality. Still, it is personal initiative that determines the achievement of optimal results. The prevalence of administrative career over scientific research motivation (which is more common among technical lab personnel) begins to exert a negative effect on scientific productivity at the point at which it clashes head on with scientific interests. At the same time, motivations like the urge to improve, and to raise one's pro-

fessional standards, had only a marginal influence on scientific productivity. Pelz and Andrews did not discover any correlation in their study with a motivation like the "national welfare".

For all four parameters of scientific productivity,[1] there was a direct connection with the share of internal sources of motivation for every type of laboratory and category of research staff. The urge freely to elaborate one's own ideas proved to be a much stronger motivation than even scientific orientation for the productivity of researchers with doctoral degrees (in technical laboratories this motivation turned out to be less important). Dependence on the leadership and a desire to avoid responsibility had a negative effect on productivity in all cases. At the same time, motivations like the desire to be outwardly independent, the desire to have "competent colleagues", to meet the requirements of practice, of customers, and finally, to elaborate ideas drawn from specialist writings, did not show any marked influence on productivity. What is more, the latter turned out to be proportional to involvement among researchers with doctoral degrees, but not among development engineers, who were apparently more inclined to tread the beaten path.

A study of the correlation between productivity of research staff in laboratories and the provision of all the requisites for their work, and also of the correspondence between their advancement and their self-evaluation yielded some unexpected results. The correspondence between individual desire and organisational demands turned out to be highest in research laboratories among doctors of sciences (0.5), then among those without doctoral degrees (0.4-0.3), with the lowest figure among technical lab personnel (0.3). The growth of productivity[2] depended more on the provision of the necessary working conditions (0.33) than on overall satisfaction (0.24). It turned out that the most valuable part of the scientific product originated under varying degrees of the researcher's disagreement with the organisation and that for the highest-level

[1] The number of scientific publications; the number of unpublished works; overall benefit to one's laboratory; overall contribution to science.

[2] In this case, the arithmetical mean of the contribution to science and the overall benefit produced.

researchers some discord with the organisation was stimulating (except for development projects). But there appeared to be definite limits to the beneficial effect of dissatisfaction. Sample studies of research personnel mobility show that one of its main reasons was the lower evaluation of outgoing personnel by the organisation (in terms of status and salaries), as compared with evaluation by their colleagues.

However, on the whole it is safe to say that these data on the influence exerted on scientific productivity by dissatisfaction, together with inner motivations, are an indication of the old contradiction between nonconformism and conformism, which is a reflection of the contradiction between science and organisation.

Contrary to the common view that scientific productivity is always proportionate to creative freedom, it turns out that this is true only within certain limits. Doctors of sciences, both in research and development, made a growing contribution to science only when the increase in their freedom (autonomy) reached 49 per cent. For development engineers, ancillary staff and researchers without doctoral degrees, autonomy of up to 90 per cent had a beneficial effect on productivity, after which there was a sharp drop. The optimal measure of autonomy was determined by the fact that the worse indicators of productivity resulted from the chief's personal, one-man direction of the researcher's effort, and the best, from decisions taken together by the chief and the researcher (developer) himself, or by the latter together with his colleagues. But the broader the scientific interests of the researcher, the greater the benefits of broader autonomy.

Of course, one must take a critical attitude to these observations.

Gerald Gordon, Professor of Sociology at Cornell University, interviewed 245 scientists engaged in medical sociology. Their work was evaluated on the strength of two criteria: innovation and productivity. "*Innovation*—the degree to which the research represents additions to our knowledge through new lines of research or the development of new theoretical statements, of findings which were not explicit in the previous theory." "*Productivity*—the degree to which the research represents an addition

to knowledge along established lines of research or an extension of previous theory." [1]

The heads of various medico-sociological laboratories and groups were invited to evaluate 25 reports on research taken at random. The evaluation was on the basis of a 10-point scale. The aim was not so much to obtain an evaluation of these 25 reports as to learn about the mentality of those invited to evaluate them. It turned out that not everyone made use of the whole 10-point scale, many confining themselves to three basic marks (5 and below—"poor", 6 to 9—"moderate" and 10—"excellent"). In this way, Gordon classified these men into two groups: "high differentiators" and "low differentiators". It turned out that scientific groups with a high level of innovation were led by "high differentiators". Gordon then applied a "job grade classification", under which all persons holding the same posts were classified according to informal working qualities.

The "low differentiators" proved to be incapable of evaluating their subordinates. Taking the number of patents, inventions and applied R & D proposals as an adequate indicator of creative talent, it turned out that the "low differentiators" not only failed to see the difference between highly talented and incapable staff but frequently regarded the creative worker as inept, and vice versa.

Gordon believes that the Mednick Remote Associates Test and the "differentiation" test help to measure different capabilities, and for that reason cannot be correlated with each other. The "differentiation" is an indicator of the capability to identify a problem, to draw attention to it. The Mednick Test reflects the capability to solve problems suggested or discovered by someone else. That is why it so often happens that a scientist who has successfully solved his own research problems fails to cope with his duties when he is appointed to an administrative post. The converse is also true: a scientist who has not displayed any special creative ability turns out to be an excellent laboratory chief.

Gordon's practical conclusion adds up to the following idea: when groups and teams are formed they should be

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[1] *Climate for Creativity*, p. 113.

made up of persons complementing each other, for this may help to enhance the group's creative potential. [1]

The recommendations offered by Soviet students of science in this area also accord with the complementarity (external complement) principle. Thus, a study prepared under the direction of Professor V. S. Sominsky, *Economic Problems in Enhancing the Effectiveness of Research Projects*, says that while in scientific establishments in the USSR remuneration of labour is rigidly tied to one's post, it is obvious that far from every scientist, however outstanding, can be appointed to head a section. On the other hand, the duties of chief of a large scientific section could be successfully fulfilled by a talented organiser scientist who, however, may be incapable of independently carrying on a theoretical project or an original experiment. Because of the existing system of labour remuneration, there is an urge in research institutes, development offices and institutions of higher learning to set up more and more laboratories, departments and chairs, because that is the only way to increase payments to specialists for their work.

The new salary scheme for staff at research establishments in the USSR, introduced in the sectoral institutes in 1970, and in some academic institutes two years later corrects the salary discrepancy among the basic categories of staff, while simultaneously raising the general level of their remuneration. [2]

Motivation in Scientific Organisations

The relationships between man and organisation in science and technology are a fairly new field of study in the science of science. Some analysts consider the influence of the collective on the motivation underlying scientific and technical creativity on the strength of data provided by socialist creative groups, which operate in conditions that are fundamentally different from those of similar groups in the capitalist countries.

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[1] *Climate for Creativity*, p. 115.

[2] *Economic Problems in Enhancing the Efficiency of Research Projects*, Leningrad, 1972 (in Russian).

On the basis of a study by the Social Institute of Worker-Researchers at the Omsk Tyre Plant and the summer schools of the all-Siberian physico-mathematical and chemical olympiads under the Siberian Branch of the USSR Academy of Sciences, Frolov found the greatest stability in the first group of motivations: the spirit of inquiry, cognition and exploration, in accordance with the subject-matter of activity. "The movement of the inventor's creative thought inevitably 'meshes' with some adjacent areas of activity, including theoretical areas of a higher order (with a more complex system of symbols). The assimilation of these areas frequently turns out to be beyond the reach of the individual, whereupon the collective operates as the vehicle of the kind of knowledge that is necessary for successful creative activity. The important thing to emphasise is that here, the creative individual has especially favourable conditions also in the sense that the necessary information is always 'to hand' and is always available as soon as the need for it arises." Having in mind above all the creative cooperation within the Social Institute's framework between worker-inventors and engineers and technicians, Frolov writes: "This kind of knowledge 'injection' based on the specific experience of only one part of the system with 'cross incentives' may erode its conformism, while the information, used until then in stereotype operations, is given a fresh lease of life, in creative acts." [1]

The author backs up his interesting observations with an analysis of a discovery made by members of the Institute (operating within the "engineer-workers-engineer" system) of a low-cost and high-efficiency tyre protector. A group making use of "cross incentives", he adds, accelerates the process of invention or discovery, and does more to awaken or satisfy the spirit of inquiry, so producing additional creative motivations. [2] Let us note that the form assumed by the Social Institute, which helps to cooperate the creative efforts of worker-innovators, engineers and industrial scientists is a reflection of the specific features of the social system. Its framework turns

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[1] *Scientific Creativity*, Moscow, 1969, p. 276 (in Russian).
[2] Ibid., p. 277.

out to be sufficiently broad to extend communications in the organisation up to the level of a collective "information bank" and to invest scientific information processes with the creative character, while substantially reducing conformism through a system of "cross incentives" (the research engineer stimulates new ideas among workers, who do the same for the engineer). In this way, a real basis is created for overcoming the contradiction between organisation and science.

The second group consists of motivations of personal concern, self-assertion, emulation and success. These motivations, which US psychology specifically emphasises, are also substantially modified in the conditions now being considered. "The motivation of direct material gain, ambitions and egoistical urges are definitely pushed into the background. The participants do not receive any direct material inducement. The very fact of joining the collective [the Social Institute—*Author.*] implies the waiving of some personal advantages and interests in favour of social interests." [1] How is this compensated? This is done by the opportunity to stage bold and frequently risky experiments and involvement in creative activity in the broad sense of the word. Besides, successful activity at the Social Institute helps to establish the standing of its participants in the production collective as specialists, while enhancing their self-evaluation and inner motivation.

The third group of motives consists of higher social inducements and an urge to benefit the whole of society, and is especially characteristic.

According to V. V. Poshatayev, "the collective is an association of men and women characterised by a community of purposes, interests and joint activity in favour of society, and which has organisation, discipline and mutual responsibility of the individuals and relations of comradely cooperation". [2]

Pelz and Andrews did not find any correlation between scientific productivity and a motivation like "national welfare". In his article, Frolov shows that under social-

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[1] *Scientific Creativity*, p. 277.

[2] V. Poshatayev, *Is One to Become a Modern Leonardo?*, Moscow, 1970, pp. 28, 29 (in Russian).

ism this motivation sets off a chain reaction involving motivations of the first and second groups and now and again having the prevalent role to play at the subsequent stages of the creative process. [1]

Some aspects of the relationship between man and organisation in science and technology are brought out by a poll of research staff in the USSR which was taken through *Literaturnaya Gazeta*. On July 15, 1970, it carried the results of a poll under the title "How Do You Feel Working?" Nearly 4,000 filled questionnaires were received, many appended to long letters (some in the nature of lengthy articles) dealing with the burning problems in the organisation and evaluation of scientific work. On their own initiative, groups at six research institutes in various towns across the country organised a poll of their staff with the use of the questionnaire. Among these were two technical institutes (the Research and Design Institute of Nonferrous Metallurgy in Dzhezkazgan, and the Central Boiler and Turbine Research Institute named after Polzunov in Leningrad), two natural science institutes (the Ukrainian Hydrometeorological Research Institute in Kiev, and the All-Union Research Institute for Nuclear Geophysics and Geochemistry in Moscow), one medical institute (the Institute of Clinical and Experimental Surgery of the Ministry of Public Health of Kazakhstan in Alma Ata), and one social science institute (the Institute of Economics of the Academy of Sciences of the Estonian Republic in Tallinn).

Regardless of the profile of the institute, between 50 and 80 per cent of those interviewed preferred casual contacts with their colleagues, and most of the rest—solitude and complete tranquillity, and only 10 per cent—regular contacts with their colleagues. The leaders at the technical institutes were much less inclined to solitude and tranquillity than those at the humanitarian institutes (10 per cent and 60 per cent, respectively), and more inclined to regular contacts (20 per cent and 0 per cent). The need for such contacts sprang from the very nature of the work in the technical sciences. But in other fields, including the humanities, there was an urge to protect oneself against stress, which inevitably results from

[1] *Scientific Creativity*, p. 279.

regular contacts with a large number of people under the current "information explosion". It is impossible to carry on original and creative research, to concentrate and to order one's thoughts if there is an excessive number of external excitants.

One-half of those interviewed believed lack of silence to be the main factor behind lower productivity; 40 per cent of the leaders at humanitarian and development institutes, and also senior research associates at technical institutes, 20 per cent of senior engineers and 25 per cent of senior research associates at humanitarian institutes believed that the excessive number of meetings and conferences was that kind of factor; 60 per cent of senior engineers, 35 per cent of senior research associates, 30 per cent of heads of groups at development institutes, and 30 per cent of heads of groups at one of the economic institutes believed that the atmosphere and relationships in the microcollective had an effect on creative productivity.

When considering the most important inducements in their work, the overwhelming majority of those interviewed (80-90 per cent) gave top-rating to satisfaction from the process of cognition and creativity (which well accords with the data given above). Consequently, moral inducement in science is the leading element, with material incentives in second place. It turned out that traditional motivations like repute and fame were such for only 15 per cent. The opinion of one's colleagues (also a moral motivation) was emphasised by 25 per cent of those interviewed. The following questionnaire data obtained at three scientific establishments give some idea about the state of satisfaction among research institute staff with the state of affairs in their organisations. There was not a single case in which research under the planned subject "did not altogether accord" or "accorded very little" with the scientific interests of the researchers, among whom there were doctors and candidates of science and group leaders. Only three of the 66 persons interviewed said that they were only partly interested in the subject, 29 said "in the main", and 34—"fully". By contrast, a fairly high percentage of those interviewed among the junior research associates without scientific degrees expressed dissatisfaction with their work on a

planned subject chiefly because of a low level of efficiency for themselves. [1]

Let us sort out the prevailing motivations. To do this it is worthwhile to compare the patently subjective evaluations of opinion (expressed by leaders and colleagues) with the less subjective evaluations of hindrances in the work which are essentially objective. Among the latter are, for instance, uninspiring subjects: the nature of the subjects on which work is going on, and the extent to which staff researchers are interested in the subject can provide an important indicator of the state of affairs in the scientific organisation and, to some extent, of the level of its leadership.

It is interesting to compare the data for the six institutes with the results of a random sampling of questionnaires. Each of the newspaper readers who filled in the answers anonymously did not appear as an "organisation man", that is, one on the staff of a definite establishment, but as an independent individual (especially in view of the fact that the questionnaire was published in July, at the very height of the summer holiday season). An evaluation of their opinions can provide, I believe, a sufficiently direct and objective expression of the individual's evaluation of his organisation. What does this candid shot of scientific public opinion show about the stimulating importance of the opinions of scientific leaders, on the one hand, and colleagues, on the other, and also about the negative influence of dull subjects on their work?

Let us start with a demographic characteristic. Of the women polled, 13.41 per cent, or almost twice as many as men (7.44 per cent), emphasised the stimulating influence of the opinion of their immediate superior. On the other hand, 50 per cent more women (18.45 per cent as against 12.98 per cent for men) complained about uninteresting subjects. The stimulating importance of the opinion of one's colleagues was evaluated almost equally (respectively, 35.88 and 33.95 per cent). Women are apparently less inclined to nonconformism, so that the growing number of women working at scientific research organisations in the USSR, which is several times greater than it is in the West, on the whole rather tends to

[1] *Socio-Psychological Problems in Science. Scientists and Scientific Groups,* Moscow, 1973, pp. 148-49 (in Russian).

consolidate than erode their stability. This, as I have said, has its positive (as well as negative) aspects. [1]

Table II-1

Evaluation of the Stimulating Importance of the Opinion of One's Immediate Superior (OIS) and the Opinion of One's Colleagues (OC), and Also of the Negative Impact on the Work of Uninteresting Subjects (US), as a Percentage by Age Groups, Qualification Levels (Scientific Degrees) and Scientific Posts

	OIS	OC	US
By age			
Under 25 years	17.54	25.44	17.54
From 25 to 35 years	11.40	34.78	17.46
From 35 to 45 years	8.08	38.83	14.10
From 45 to 60 years	5.15	33.60	9.21
Over 60 years	3.89	32.30	10.12
By scientific degrees			
Without scientific degrees	13.47	32.61	21.07
Candidates of science	6.97	37.73	11.39
Doctors of science	2.59	34.20	6.37
By scientific posts			
Engineers	12.26	25.81	27.74
Junior research associates	15.20	32.60	18.41
Senior engineers	9.55	32.27	25.45
Senior research associates	9.29	38.00	15.53
Heads of laboratories and sectors	6.46	37.78	11.87
Heads of scientific establishments	—	40.66	7.69

[1] By contrast, for all those who emphasised the opinion of their immediate superior as a motivation, 66.77 per cent were men and 33.23 per cent were women, or only half as many. Among those who emphasised the opinion of colleagues, the proportion was even 79.28 to 20.72, which is 4 times as many as men. This apparent contradiction is due to the fact that among those who took part in the poll there were 2,943 men and only 813 women, or only about a quarter. An "equalisation" of the overall participation of men and women in the poll would yield a more adequate picture of scientific public opinion on the strength of the data from the foregoing paragraph.

Let us consider the data in Table II-1.

These data show that in the under 25 age group 17.54 per cent of those polled identified as a motivation the opinion of their immediate superior; in the 25-35 age group, 11.40 per cent; in the 35-45 age group, only 8.08 per cent, in the 45-60 age group, 5.15 per cent; and in the over 60 age group, 3.89 per cent. Consequently, with age the evaluation steadily and markedly declines. There is also a reduction in the share of those complaining about uninteresting subjects. On the other hand, the opinion of one's colleagues gradually becomes more important with age, going up from 25.44 per cent for the under 25 age group to 34.78 per cent in the 25-35 age group, and to 38.83 per cent in the 35-45 age group. In the older age groups it declines (to 33.60 in the 45-60 age group and to 32.30 per cent for those over 60), but on the whole remains much higher than it is among young scientists.

We find a similar picture in the classification by qualification level (scientific degrees). The evaluation of the opinion of one's immediate superior tends to fall with the higher degree, from 13.47 per cent among those without scientific degrees to 6.97 per cent among candidates and 2.59 per cent among doctors of science. But it is a characteristic fact that the share of complaints about uninteresting subjects (in which one's immediate scientific superior is always directly involved) tends to fall almost in the same proportion. But the evaluation of the opinion of one's colleagues goes up from 32.61 per cent to 37.73 per cent and 34.20 per cent, respectively.

In other words, it is not only experience in life, but also scientific qualification that induces one to rely more on oneself in relations with one's superiors, while putting a higher value on the opinion of those who have the same status in the organisation. This is also borne out by the evaluations classified by post. A higher value on the opinion of one's immediate superior is put by engineers (12.26 per cent) and junior research associates (15.20 per cent) than by senior engineers (9.55 per cent) and senior research associates (9.29 per cent), and heads of laboratories and sectors (6.46 per cent). But the opinion of colleagues is valued less by engineers (25.81 per cent) than senior engineers (32.27 per cent), and by

junior research associates (32.60 per cent) than senior research associates (38.00 per cent), heads of laboratories (37.78 per cent) and especially heads of scientific establishments (40.66 per cent).

Let us note that among the engineers (that is, working mainly in the technical fields) both these parameters of organisational evaluation present a different picture: a lower value is put on the opinion of colleagues, and there are considerably more complaints about uninteresting subjects than there are among researchers in the exact, natural and social sciences. This is, in the main, borne out by the distribution of evaluations by fields of knowledge (see Table II-2).

Table II-2

Evaluation of the Stimulating Importance of the Opinion of One's Immediate Superior (OIS) and the Opinion of One's Colleagues (OC), and Also of the Negative Impact on the Work of Uninteresting Subjects (US), as a Percentage by Scientific Disciplines

Scientific disciplines	OIS*	OC**	US
Medical	14.21	32.99	15.48
Chemical	13.06	34.68	13.96
Mathematical	11.71	37.84	14.41
Economic	11.02	30.61	16.10
Physical	9.71	37.54	11.33
Biological	7.89	36.86	9.32
Humanitarian	6.97	34.16	11.91
Technical	6.96	35.97	15.94
Geological	6.47	39.36	15.60
Pedagogical	6.17	29.63	8.64

* mean = 10 per cent
** mean = 35 per cent

The highest value of the stimulating importance of the opinion of one's immediate superior is given by medical men (14.21 per cent), followed by chemists (13.06 per cent), mathematicians (11.71 per cent) and economists (11.02 per cent). Then come the physicists

(9.71 per cent), the biologists (7.89 per cent), workers in the humanities (6.97 per cent) and technicians (6.96 per cent), the geologists (6.47 per cent) and teachers (6.17 per cent). The evaluation of the opinion of one's colleagues has a very different hierarchy. Here, the geologists come first (39.36 per cent), mathematicians second (37.84 per cent), and physicists third (37.54 per cent). They are followed by the biologists (36.86 per cent), technicians (35.97 per cent), chemists (34.68 per cent), and workers in the humanities (34.16 per cent). At the bottom of the list are the medical men (32.99 per cent), economists (30.61 per cent), and teachers (29.63 per cent). On the other hand, uninteresting subjects are a source of pain for 14-16 per cent of the medical workers, chemists, mathematicians, economists, technicians and geologists, for 11-12 per cent of the physicists and workers in the humanities, and for 9 per cent of the biologists and teachers.

Consequently, the evaluation of the leadership tends gradually to drop from a maximum among specialists in medicine to specialists in the natural and exact sciences, and even more markedly in the humanities. But this rule, however, also has its exceptions. To sort these out, let us assume 10 per cent of those polled to be the mean evaluation obtained in a sampling taken at six institutes. We find the evaluation of the leadership by medical workers, chemists, mathematicians and economists to be higher than the mean, and by physicists, biologists, geologists, technicians, workers in the humanities and teachers, below the mean. It is at present hard to say to what extent this distribution has been influenced by the "mathematicisation" of the economic and other sciences, on the one hand, and the "technicisation" of some natural and humanitarian sciences, on the other.

Nor is it likely that the answer is mass incompetence among the leaders, as will be seen, say, from the fact that a clear minority in every field is dissatisfied with the exercise of the key functions of leadership, namely, the selection of subjects and regulation of the volume of work. Shortcomings like uninteresting subjects (and even an excessive number of subjects and excessive volume of work) were noted only by 16-18 per cent of those polled. Consequently, there are no grounds for the assump-

tion that the overall level of scientific leadership is low.

In the distribution of another organisational parameter—the opinion of one's colleagues—it is natural to adopt 35 per cent of those polled as the mean evaluation. Above the mean we find evaluations by the geologists, who come first, whereas in the evaluation of the leadership's opinion they rank last but one. They are followed by the mathematicians, physicists, biologists and technicians. Below the mean we find evaluations by the chemists, workers in the humanities, medical men, economists and teachers.

The relatively low (7-14 per cent) evaluation of the stimulating importance of the opinion of one's immediate superior by workers in every scientific field is, to some extent, a negative result of the growing collectiveness of scientific activity, for the immediate superior is regarded "as one of us", but who has been vested with power, which is why he has the duty to be infallible. Besides, the nonconformist character of research prevents the opinion of the immediate superior from being regarded as an important inducement. This aspect may not be as pronounced among the medical men (14.21 per cent), chemists (13.06 per cent), mathematicians (11.71 per cent), and economists (11.02 per cent).

Indeed, a prophet is without honour in his own country. The replies to almost all the points of the questionnaire, the evaluations of the heads of laboratories or groups, on the one hand, and of senior research associates (senior engineers) on the other, turned out to be very close or identical to each other. It seems that in subjective outlook, the leader of a primary research group differs little, if at all, from the leading researchers, who are his subordinates. They, for their part, do not usually regard him as a "superior", but as "one of us", who merely has additional administrative duties to perform (for a definite reward). This attitude is shared by the bulk of the research staff and engineers. It is not surprising, therefore, that all the promising ideas and correct decisions coming from the leader are taken for granted. Equally, it is not surprising that any hopeless idea or incorrect, and especially "unfair" decision is met with resentment, precisely because of the intimacy of the relationship. There is perhaps good reason why the opinion

of one's immediate superiors ranks on roughly the same level as that of one's intimates, for it is hard to discern the features of another face when standing nose to nose. [1]

Professional repute turns out to head the list of the most acceptable criteria of scientific productivity: more than one-half of those polled at the six institutes emphasised the share of publications receiving recognition by specialists, and this comes closest to the indicator of the relative contribution to science given by Pelz and Andrews. A parameter like overall benefit to the organisation may be compared with the economic effect obtained, and also the existence of students and followers. An average of 40 per cent of those polled emphasised economic effect, with the figure going up to 60 per cent among the leaders of development engineers (and senior engineers), and to 80 per cent among junior research economists (who also laid stress on the share of recognised publications), whereas the leaders of humanities groups and senior research associates at the Tallin Institute of Economics gave a lower figure of 30 per cent (as compared with 70 per cent for the share of publications); among senior research associates at the technical institute it was down to 25 per cent. Consequently, the most qualified and experienced academic economists and also partially those working in the technical sciences believed the criterion of economic effect to be less than broad or reliable to evaluate scientific work, giving preference to the share of publications recognised by specialists, that is, a broader evaluation in terms of social effect. This runs in line with the emphasis by 18 per cent of those polled of the existence of students and followers as a representative measure of productivity.

Only 12 per cent voted for the number of publications as a measure of productivity, while 20 per cent favoured the number of references to the works of a given author in the works of other authors. Neither the first indicator (which up to now remains the chief official measure of

[1] This adds meaning to the task of enhancing not only the administrative competence but also the administrative standards of the heads of research groups, and of helping them to develop self-possession and a sense of tact in dealing with their subordinates.

productivity) nor the second, proposed by some authors instead, apparently commands enough confidence on its own. It does not follow from this, however, that these cannot be useful as supplementary indicators of productivity (considering the statistical law governing the distribution of publications).

The opinion of specialists helps scientists and engineers to find their bearings in face of the information explosion. While the opinion of one's colleagues has turned out to be among the key motivations for scientific creativity, and recognition of scientific publications by specialists a key criterion of evaluation, the reading of special literature continues to be the most valuable source of information for 80 per cent of those polled (without regard to profile). Reference journals, publications of the All-Union Institute of Scientific and Technical Information rank second (about 70 per cent in the applied institutes, and 45 per cent in the humanitarian), while experimental research ranks third as a source of information (45 per cent in the technical and 20 per cent in the humanitarian institutes).

Scientific symposia and conferences have the capability of condensing information, but only if they are held on a sufficiently high level. They were recognised as a valuable channel of information by 65 per cent of senior research associates and senior engineers of technical institutes, and by 55 per cent of the heads of sectors and senior research associates in the humanities. The evaluation of these is substantially lower by leaders of applied groups (30 per cent), and junior research associates in the humanities (20 per cent). It appears that those who gave a higher evaluation have, on the whole, more opportunities for informal contacts at symposia and conferences allowing them to obtain information more selectively condensed.

Consequently, the problem of man and organisation in science and technology is closely interwoven with the problem of science and organisation within the system of social productive forces. Indeed, the latter actually becomes a system only on the basis of the synthesis of science and organisation. But the way to such a synthe-

sis is long and hard. It runs through the resolution of contradictions, which can be resolved only with the conversion of the scientific organisation into a creative group yielding a measure of optimal conjunction of diversity and choice, of the personal and the social. Only a society which adopts this as its guiding principle and which refuses to be satisfied with organisational palliatives opens up the way to a synthesis of science and organisation, and so to the solution of the human problems in scientific organisation.

Chapter Three

Division of Labour in Science

The current scientific and technical revolution entails intensification of the social division of labour, involving the origination and accelerated growth of new spheres for the application of labour and the emergence of new types of labour. There appears to be a decline in the share of those employed in agriculture and the extractive industries, and a growth in the share of those employed in manufacturing, construction and, especially, in the sphere of the services, both material and nonmaterial, including science and scientific services. There is a growth in the socialisation of labour: with the scientific, technological and organisational complexification of production, there is a marked enlargement of the composition of the collective labourer. At the same time, there is a substantial change in the quality of labour, which becomes ever more complex. "And whereas in quantitative terms," says Marx, "direct labour is reduced to a smaller share, in qualitative terms it is converted into a secondary, even if necessary, element with respect to the universal scientific labour, with respect to the technological application of natural science, on the one hand, just as it is with respect to that universal productive force which originates from the social break-down of labour in collective production and which appears as a natural gift of social labour (although it is a historical product)." [1]

It was industrialisation which provided a powerful impetus to these processes. First, there appeared a *professional* division of labour in accordance with various

[1] Karl Marx, *Grundrisse der Kritik der politischen Ökonomie (Rohentwurf) 1857-1858*, S. 587-88.

types of social production activity. The division of labour between the major spheres of this activity was called by Marx the general division of labour, subdivided into particular subtypes. On the other hand, there appeared a division of labour in accordance with the various *technical* functions (specialties) performed within the framework of the given and the other trades. With the technical division of labour is closely connected the unitary division of labour within the shop (as between a tool-setter and a machine-tool operator).

With the growth of capitalist production in breadth and the formation first of the national and then of the world markets, the *territorial and international division of labour* takes shape. The vertical hierarchy in the social division of labour is complemented in the horizontal by the territorial division of labour within the country, and by the international division of labour in its external connections.

In the course of the current scientific and technical revolution, scientific organisation (a synthesis of science and organisation) has left its mark on the state and prospects for the further development of society's productive forces and the social division of labour. A most important expression of this was the emergence of science organised in social terms, of *scientific activity* as a major sector of the national economy. Its development is inseparable from the scientific transformation of the whole of production. Consequently, it is now already possible to consider the advent of a new and major stage in the social division of labour which is connected above all with the growing role of science and of scientists in the development of society.

The new stage in the social division of labour, which is determined by the current scientific and technical revolution, is also having an effect on science itself. This is determined by the whole system of interaction between society and science, which becomes a leading element of the social productive forces. The growing demand for scientific knowledge and methods in various spheres of social life, above all, the "scientification" of social production, and the conversion of science into a key object and instrument of state policy work a substantial change in the very make-up of scientific activity.

Formative Period and Substance

Scientific work began to stand out among the other types of human activity with the same historical necessity that has marked the whole development of the social division of labour. Science originated above all from the needs of social production, which had by then become so complex that it was no longer capable of further development on a purely empirical basis, through trial and error. That is why, although the accumulation of human knowledge has a history behind it which runs to thousands of years, the origination of science in the modern sense of the word is generally dated from the 17th century, the start of the new period. Then it was that Francis Bacon declared in the country of the first bourgeois revolution: "Knowledge and human power are synonymous, since the ignorance of the cause frustrates the effect." [1]

In his famous utopia, *New Atlantis*, Bacon presented the picture of a fairly subtle technical division of labour among the members of "Solomon's House", a prototype of the Royal Society of London. "For the several employments and offices of our fellows," says Bacon, "we have 12 that sail into foreign countries ... who bring us the books, and abstracts, and patterns of experiments of all other parts.... We have three that collect the experiments which are in all books.... We have three that collect the experiments of all mechanical arts; and also of liberal sciences; and also of practices which are not brought into arts.... We have three that try new experiments, such as themselves think good.... We have three that bend themselves, looking into the experiments of their fellows, and cast about how to draw out of them things of use and practice for man's life and knowledge, as well for works, as for plain demonstration of causes, means of natural divinations, and the easy and clear discovery of the virtues and parts of bodies."

After a discussion of all these works at general meetings of the members of Solomon's House, there are "three that take care ... to direct new experiments, of a higher light, more penetrating into nature than the former".

[1] Francis Bacon, *Novum Organum*, New York, 1902, p. 11.

There are "three others that do execute the experiments so directed, and report them". Lastly, there are "three that raise the former discoveries by experiments into greater observations, axioms, and aphorisms". At Solomon's House there are also "novices and apprentices, that the succession of the former employed men do not fail: besides a great number of servants, and attendants, men and women". [1]

Like material production, the development of the social division of labour in science became the basis for the cooperation of workers brought together within the framework of the early scientific societies, academies and universities. Even at the early stages of its development this cooperation helped to raise the productivity of scientific labour both in the phase of data collection, and in the phase of discussion of the results obtained, the exchange of publications and opinions.

Adam Smith, among the first to formulate the doctrine of the social division of labour, in his main work specifically dealt with the division of labour in science. He wrote: "Like every other employment too, it is subdivided into a great number of different branches, each of which affords occupation to a peculiar tribe or class of

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[1] *The Works of Francis Bacon,* Vol. II, pp. 115-16.

Let us note that the latter remark refers not to a technical but to a demographic division of labour in science. The indication that women, alongside with men, are involved in scientific activity, even if in ancillary roles, was as much ahead of its day as Bacon's prediction of a number of technical innovations, which were realised only in the 20th century. For over three centuries, the Charter of the Royal Society of London barred women from its staff, and that was not an exception but the rule. The involvement of young people in science was somewhat more favourable, and this the author of *New Atlantis* justly regarded as an earnest of continuity in research. This applied especially to the scientific societies which emerged in North America. In Europe, science still remained mostly a kind of hobby, a pursuit for old and wealthy amateurs. Georg Christoph Lichtenberg, the outstanding German thinker and scientist, and a contemporary of the Great French Revolution, expressed this in a vision: "It would be happiness, indeed, if every age and every year worked for the benefit of the others; if one made the wheels, another the springs, a third the face, and a fourth perhaps completed the fashioning of the clock as a whole" (*Georg Christoph Lichtenbergs Aphorismen,* Hrsg. von A. Leitzmann, 2. Heft: 1772-1775, Berlin, 1904, S. 32).

philosophers, and this subdivision of employment in philosophy, as well as in every other business, improves dexterity and saves time." [1]

The deepening division of labour in science, as of the social division of labour as a whole, also had its negative aspects. Thus, Engels explained the narrowness and empiricism of science in the first three decades of the 19th century by the division of labour that had come to dominate natural science in that period, "which more or less restricted each person to his special sphere, there being only a few whom it did not rob of a comprehensive view". [2] This applied especially to the professors of universities in feudally fragmented Germany, whom Lichtenberg harshly ridiculed. [3]

Deepening Technical Division of Labour

Throughout the 19th century and the first half of the 20th century, the trend towards a further differentiation and specialisation of the sciences was not compensated by a countertrend towards their integration. The result was an ever narrow specialisation of scientists and research establishments in accordance with steadily fragmenting fields of knowledge, isolated from each other by the "language barrier" of special terminology. This determined the development to the limits of the *professional division of labour* in science.

At the same time, the equipment of institutes and laboratories with new research apparatuses and instruments, and the use of electronic computers called for a further deepening of the *technical* and *positional* division

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[1] Adam Smith, *An Inquiry into the Nature and Causes of the Wealth of Nations,* London, New York, s.d., p. 8.

[2] Frederick Engels, *Dialectics of Nature,* p. 28.

[3] "He was not so much the proprietor as a tenant of the sciences which he taught, because he owned not a scrap of these," Lichtenberg wrote about one of these "titular" professors. "Of course, the ancients surpassed us: 1) Because they were not constantly engaged in imitation; 2) were not dogmatic; 3) made a study of things rather than of words; 4) were freer; 5) did not have to write to earn their daily bread; and 6) saw more of nature." (*Georg Christoph Lichtenbergs Aphorismen,* Hrsg. von A. Leitzmann, 3. Heft: 1775-1779, Berlin, 1906, S. 110; 2. Heft: 1772-1775, S. 138.)

of labour between the theoreticians and the experimentators, between lab assistants and researchers, and then also between senior and junior research associates, and heads of groups, laboratories and institutes. The overall picture of the division of labour in modern science has become exceptionally complexified. This complexity, importantly compounded by the differentiation and integration of knowledge, is reflected, in particular, in the abundance of definitions describing the various types and subtypes of present-day scientific activity. Two Soviet authors say: "The complexity of present-day scientific problems and technical systems results in both a narrow specialisation in science on subject lines, according to the field of research, and on technological lines, according to the type of scientific work. The origination of complex problems requiring a conjunction of specialised sectors raises the question of the mode of administration which could help to overcome the restrictive trends of specialisation." [1]

In her interesting book, *The Scientist and Modern Science,* [2] Y. Z. Mirskaya justly connects the differentiation of science with the "differentiation of specialists in accordance with the *content of knowledge*", and also the differentiation of scientists according to the *mode* in which existing knowledge is used (theoretician-experimentator, analyst-synthesist, and so on). In the conditions of "Big Science" with its complex problems, these distinctions are compounded by the *functional* division of labour as entrenched in the staff establishment. The author contrasts the "natural" division of labour depending a) on scientific specialty and b) on the personal qualities of scientists, and the "unnatural" division of labour in accordance with the "organisational and functional" principle. She adds: "We call it 'unnatural' because it is, first, connected not with the requirements of science itself, but with the requirements of the present-day forms of its organisation, second, because it assigns to members of the group a definite type of work which far from always

[1] Y. V. Kosov, G. K. Popov, *Administration of Intersectoral Scientific and Technical Programmes,* Moscow, 1972, p. 30 (in Russian).

[2] Y. Z. Mirskaya, *The Scientist and Modern Science,* Rostov, 1971, p. 30 (in Russian).

meets their capabilities and interests, and third, because this division of labour fixes a clearly temporary and abnormal state of affairs in present-day science, which consists in the fact that a large part of those involved is engaged in uncreative work." [1]

However, this line of reasoning is not altogether unquestionable. First, when contrasting the requirements of "science itself" and the "present-day forms of its organisation", one should not forget that for all the contradictions between science and organisation, their synthesis—scientific organisation—constitutes the core of the current scientific and technical revolution and reflects a vital requirement of "Big Science". Second, the "definite type of work which far from always meets their capabilities and interests" used to be assigned to members of groups by the earliest division of labour by sex and age, which did not prevent it from being (and being called) natural. Strictly speaking, this term is more justified than it is in the author's use.

Finally, third, the "state of affairs in present-day science, which consists in the fact that a large part of those involved is engaged in uncreative work" can hardly be characterised as "clearly temporary and abnormal". Indeed, "Big Science" in our day is a massive and collective phenomenon in contrast to the "Small Science" of the past. Clearly, the 4-million-strong army of research workers in the modern world cannot (and must not) consist only of "creative individuals" in the sense of those who had worked in "Small Science". But that is not to say that the bulk of scientific workers is not, in general, engaged in creative endeavour. The division of labour produces a totally different effect: the creativity of the researcher formulating a new scientific theory is no longer possible without the creativity of the experimentator, just as the latter's is impossible without the creativity of the designer of scientific equipment, and the creativity of all, without the creativity of those who fabricate the electronic computers, and so on. In other words, creative work has become much more diverse, of highly differing profile and effected at different levels. This is by no means tantamount to a "depreciation" of scientific

[1] Y. Z. Mirskaya, op. cit., p. 43.

creativity. There is—and always will be—enough room for creativity in scientific life.

The UNESCO report says: "The atmosphere prevailing in a laboratory actively engaged in research is one of excitement. To the scientist, working is the most fascinating game: his free imagination can set the rules and change them, so that his unlimited curiosity may find pause and satisfaction. The scientist is a lucky player, for the toy he is playing with is constantly changing and has no boundaries: the toy is the universe." [1] The same ideas were expressed by Kepler, Einstein and James D. Watson (in his well-known autobiographical work, *The Double Helix*).

But science is not the concern of just a handful of the elect. "For it is necessary to insist upon this extraordinary but undeniable fact," states the Ortega Hypothesis: "experimental science has progressed in great part thanks to the work of men astoundingly mediocre, and even less than mediocre. That is to say, modern science, the root and symbol of our actual civilisation, finds a place for the intellectually commonplace man and allows him to work therein with success. In this way, the majority of scientists help the general advance of science while shut up in the narrow cell of their laboratory, like the bee in the cell of its hive, or the turnspit in its wheel. And, judging from its dances, it may well be that the bee is exhilarated in the cell of its hive." [2] As the British scientist Ronald Norrish, 1967 Nobel Prize Winner in chemistry, urges, the need to recognise and formalise in organisation a division of labour in science between the few high-level theoreticians and the individuals paving the way to new discoveries. While encouraging the "high flight birds", one should also value the indispensable men and women who "are not inventive", but who are capable of fulfilling in science the role of skilled and well-qualified technicians and artisans. The latter should be separated from the former and brought together in different streams of education.

This recommendation can be accepted only with a grain of salt, as otherwise it can do more harm than

[1] *Science and Human Needs*, p. 1.
[2] Ibid., p. 12.

good. There are, for instance, the highly indicative results of a British sociological experiment in which rank-and-file assistants and laboratory technicians were given a free hand and within a short period proposed a number of valuable scientific ideas and technical inventions, including one of national importance.

The division of labour in science should not in any way upset this principle of creative democracy.

The Declaration on the Rights of Scientific Workers, adopted in 1969 by the World Federation of Scientific Workers, says: "A scientific worker is considered to be a suitably qualified person engaged in professional work in natural, technological or social science, in fundamental or applied science, and in the teaching of science....

"A professional scientific worker is deemed to be qualified by the possession of a university degree or diploma of equivalent standing in one of the sciences.

"Notwithstanding this basic requirement, and without lowering the general standard, individuals who lack some of the formal academic certificates, may qualify by possession of valuable experience and by holding responsible posts demanding high scientific attainments or by publications or achievements of acknowledged standing."[1]

I feel that it would be more correct to consider the division of labour in modern scientific groups not in terms of functions or organisational functions but of technology and positions.

The technical division of labour is based on a spontaneously shaped demarcation of the research process into successive studies, from the birth of a scientific idea to its realisation in one form or another. This demarcation is reflected in the well-known international classification of basic research, applied research, and development.

Of course, it is still true, as Academician P. L. Kapitsa once said, that "this division should largely be considered artificial, for it is hard to pinpoint just where basic science ends and applied science begins.... This division ...

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[1] *Scientific World* No. 4, 1969, p. 23. A recommendation on the status of scientific workers adopted by the Federation in 1974 leaves it up to the member states to decide on the final definition of the category of persons they classify as their scientific workers (*Scientific World* No. 2, 1975, p. 4).

has more to do with the need to finance, plan and control scientific work.... In the activity of various prominent scientists it is hard to determine when they had an applied goal and when a cognitive one in mind." [1] Academician Kapitsa is himself a scientist tackling both fundamental scientific problems and major engineering tasks, [2] and this is quite natural. Every real (true) scientific idea strives towards its embodiment in social production, however long and thorny the way from its origination in the scientist's head to some form of use in the interest of society.

From the standpoint of the technical and professional division of labour in scientific activity it is interesting to compare the features of the technical sciences with those of the natural and social sciences, as brought out by means of a questionnaire. One is struck by the fact that there is a *high similarity* in the distribution of the answers obtained from workers in the various fields of science, and consequently largely of science and technology in general. This clashes with the view that there is a gap between science and technology, between research and development. [3]

According to the classification proposed by the Stanford Research Institute, "vertical technology transfer" is moving from the discovery phase and the creativity phase

[1] *Science Today* (Collection), Moscow, 1969, pp. 110-11 (in Russian).

[2] In his famous lecture on "The Two Cultures", C. P. Snow recalled: "Rutherford himself had little feeling for engineering. He was amazed—he used to relate the story with incredulous admiration—that Kapitsa had actually sent an engineering drawing to Metrovick, and that those magicians had duly studied the drawing, *made the machine*, and delivered it in Kapitsa's laboratory!" (C. P. Snow, *Public Affairs*, London, 1971, p. 32.)

[3] This view was expressed, among others, by Professor Derek J. de Solla Price in a report at the XIII International Congress of the History of Science held in Moscow in 1971, and has its origins in Snow's conception of "the two cultures". But I must note that, far from insisting on the global universality of this conception, the author himself in fact remarked on the great distinctions in this matter in the various countries. "I believe," Snow wrote, "the Russians have judged the situation sensibly. They have a deeper insight into the scientific revolution than we have, or than the Americans have. The gap between the cultures doesn't seem to be anything like so wide as with us." (C. P. Snow, *Public Affairs*, p. 35.)

(leading to invention) to the substantial phase and development phase (leading, for example, to a prototype) and is followed by the engineering phase (leading to a functional technological system).[1] But precisely in order to cut short this path and to clear it of any superfluous obstacles, there is need to differentiate the organisation of labour at the various stages of research. To that extent, the social division of labour in science should be effected with an eye to the specifics of fundamental research, applied research, and development.

At this point, we should consider the demarcation between the conceptions of "fundamental science" and "fundamental research" (of which all the other types of research are derivatives).

The correctness and authenticity of scientific hypotheses and theories depend on the solidity of the fundamental knowledge on which they rest. The fundamental sciences help to accumulate and order such knowledge on the structure of matter, and the laws governing its motion and development. Since antiquity, the fundamental sciences have included mathematics, mechanics and physics, and subsequently also chemistry and biology. The applied sciences, as the name itself indicates, deal with the application of fundamental scientific knowledge to the solution of various practical problems, as the technical, agricultural and medical sciences, among others, do.

But it was discovered in the course of the past century that the division of the sciences into fundamental and applied in the then accepted sense (which was, in particular, the basis for the emerging professional division of scientific labour) was very tentative. First, some fundamental discoveries have been applied in practice right away, without going to the medium of applied science, and conversely, some such discoveries were made in the applied sciences (like radio).[2] Second, suc-

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[1] Erich Jantsch, op. cit., p. 15.

[2] Let us recall that Mendeleyev, the author of the famous Table of Elements and the periodical law on which it is based, was head of the Chamber of Weights and Measures and was at one time refused membership of the Imperial Academy of Sciences in St. Petersburg, where the periodical law was seen as no more than a bold assumption (*Science Today*, p. 231). Here is another example: Irving Langmuir, the winner of a

cesses in German philosophy, English political economy and French social thought, and especially the development on the basis of these achievements of the scientific theory of social development, helped to extend the range of the fundamental sciences, which now include, along with the exact and natural sciences, also the social sciences, although this has not yet been generally recognised. The social tenor of the sciences necessarily causes individual scientists and various social groups to take an impassioned attitude to them.

Today it is more usual to speak of basic and applied *research* instead of the fundamental and applied *sciences*. Such research may cover any field of science, including exact, natural and social, but more frequently bears on whole complexes of sciences, which is especially characteristic of science today. *Basic research* may be "pure", where the researcher seeks the solution of a purely cognitive task (as the proof of a theorem), or "objective research", when he sets himself a *scientific* objective, which is, as a rule, some aim that is not directly connected with practice. The methods used in tackling basic research problems may be either experimental or theoretical, although basic research is frequently identified with theoretical.[1] By contrast, *applied research* has the task not so much of obtaining fundamentally new knowledge as of applying the available knowledge to the attainment of some practical goal (like reducing energy losses in long-distance power transmission).

Nobel Prize in physics, made several fundamental discoveries in electronics and vacuum physics while working at the industrial laboratory of General Electric.

C. P. Snow remarked: "Pure scientists have by and large been dim-witted about engineers and applied science. They couldn't get interested. They wouldn't recognise that many of the problems were as intellectually exacting as pure problems, and that many of the solutions were as satisfying and beautiful." (C. P. Snow, op. cit., p. 32.)

[1] According to Erich Jantsch, "fundamental research is research on the fundamentals of science and technology. Fundamental scientific research broadly pertains to the level of scientific resources (natural laws, principles, theories, etc.) and fundamental technological research to the level of technological resources ... in the technology transfer space" (Erich Jantsch, op. cit., p. 15).

However, even applied research does not quite solve the problem of combining science and production, for this is a mission which falls to development, that is, experimental and design work that carries the results of applied research to practical application in industry, agriculture, transport, public health, and so on.

The currently adopted division into basic research, applied research and development was proposed for purely administrative purposes first by the US National Science Foundation, and then by UNESCO and the Organisation for Economic Cooperation and Development (OECD). This division may be said to have reached the stage that could be compared to the stage in the development of the classification of the sciences in the 19th century, when, according to Academician B. M. Kedrov, "the overall tendency towards the differentiation of sciences leading to their detailed specialisation and the consequent one-sidedness was also reflected in the concrete methods used in solving the problem of science classification.... One could say that the principles of science classification were themselves subjected to differentiation, as a result of which there began to emerge one-sided specialised systems based on some special principle carried to its fullest possible development, but to a development that was lopsided, through the neglect of the other aspects of the overall connection of the sciences or of their subordination to the given principle". [1]

Academician Kapitsa used to say that while the accepted division was convenient from the administrative standpoint, it did not reflect the continuity of the actual process of research, where one stage imperceptibly fades into another. Replying to my question, Academician A. N. Nesmeyanov expressed a similar view, stressing that he would not put his name down to the classification of science into basic research, applied research, and development.

Harold Himsworth, former Professor of Medicine at London University and Secretary of the Medical Research Council of Great Britain, contrasts this classification with the continuity of stages in research, their intercon-

[1] B. M. Kedrov, *Classification of the Sciences*, Vol. I, Moscow, 1961, p. 90 (in Russian).

nection and interdependence, and reflection in their succession of the natural succession of the processes being studied. Thus, in Himsworth's field of research this kind of "intellectual continuum" is made up of processes and phenomena at a clinical, and then a pathological, physiological, biochemical and other levels, down to the molecular level. He adds that the specialised and esoteric nature of the knowledge reaches a maximum on the periphery and goes down to a minimum at the centre of the given field of science. In other words, the more applied the research, the more specialised it is. Conversely, the more grounds we have for designating it as fundamental science, the less closed in it is upon itself within a specialty, and the more general and abstract its character.

"Pure science", which is natural and even necessary here, at the centre, is unacceptable and intolerable on the periphery, along the boundaries of the special field of knowledge. Accordingly, Himsworth suggests as the basic criterion for classifying the individual types of research the degree of their specialisation, that is, the extent to which this research and development is remote from the centre of the given special field, because it is these "natural successions" from specialised to nonspecialised scientific disciplines that constitute the structure of modern scientific knowledge. [1]

A critical evaluation of the existing classification of the types of research has some grounds. One of its obvious flaws is the subjective character of the criteria on which it is based. Thus, the statistical record of the individual types of research is based on an evaluation of the objectives stated by the researcher himself. For that reason, these statistics cannot claim great precision, although the subjective mistakes and errors in evaluation are to some extent mutually compensated according to the law of big numbers. It is natural, therefore, that scientists, like scientific administrators, should seek a more reliable and objective criterion. Unfortunately, the criterion of the extent of specialisation, suggested by Professor Himsworth and some other scientists, also has

[1] Harold Himsworth, *The Development and Organisation of Scientific Knowledge*, London, Heinemann, 1970, pp. 13, 24, 47.

an element of subjectivism and is, for that reason, latent with mistakes, like the now accepted criteria. The truly objective criteria, suggested at various periods by Professor J. D. Bernal in Great Britain [1] and also by Professor B. G. Kuznetsov in the USSR [2] are based on a consideration of the ultimate effect of basic research. This is evidently a criterion that could be adopted only in retrospect, with the benefit of considerable hindsight.

The way out today appears to lie in the continued use of the generally accepted classification of the types of research, while bearing in mind that there are no absolute watersheds between the types and that they are mutually complementary, for without this it will be impossible to augment human knowledge.

Professor Bernal believed, in this context, that it would be appropriate to start from a division of research into convergent and divergent, for this "cuts right across the divisions of basic and applied research".[3] Moving in the same direction, Lord Rothschild, Chairman of the British Government's Central Advisory Council for Science and Technology, suggested that all types of research and development should be classified as pure research and applied research, which, for their part, should be subdivided into strategic research, product research, process research, and operational research.

This kind of functional classification, I think, has its advantages over the existing one, which has been repeatedly criticised not only by students of science, but also by practitioners in production.

J. J. Harwood, Manager of Research Planning at the Ford Motor Co., in the USA, says that everyone is now agreed on the need for industrial research, for R & D has done a great deal to develop industry, new lines of products, improve technological processes, and so on.

In contrast to the academic forms of research, the "supply-demand" relationship characterises the most important feature of industrial research. Industrial R & D

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[1] See, *The Science of Science,* London, 1964, pp. 302-04.

[2] B. G. Kuznetsov, *Philosophy of Optimism,* Moscow, 1972, p. 326 (in Russian).

[3] J. D. Bernal, "Strategy of Research". In: *Research,* December 1955, pp. 459, 460.

results not only in new ideas and knowledge, but makes additional demands on the organisation of scientific and technical innovations, with every company having to work out its own style to meet the specific nature of its activity. In the early 1970s, as compared with the two preceding decades, fairly important changes have taken place in the orientation of research and in the growth of its importance in the production process. Thus, there has been a shift towards programmes oriented upon cost-cutting, improvement of product quality, and improvement of the process of research itself.[1]

In the light of these changes, the Industrial Research Institute in the United States has proposed a new classification of industrial R & D: 1. Research aimed at the immediate development of existing production, improvement of product quality, increase of earnings and expansion of sale. 2. Long-term research of a general character aimed at further developing knowledge in this field which is connected with the company's activity. 3. New risky lines of research designed to win new marketing outlets in areas where the company has no production or marketing experience.

Referring to the practice of labour division in scientific activity in the USA, Chalmers Sherwin, Vice President, Special Products Division, Gulf General Atomics Corporation, has considered the lessons to be derived from Project Hindsight.

Every new system of weapons, as their analysis within the framework of the project showed, usually required from 50 to 100 major technical and scientific

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[1] Julius J. Harwood, "The Changing Style of Research in the Business Enterprise". In: *Research Managemnet,* Vol. 16, No. 5, New York, 1973.

According to a poll of R & D chiefs at 43 chemical companies in six European countries—France, FRG, Britain, Italy, Netherlands and Switzerland—the division of labour between the separate stages of scientific activity is connected with the breakdown of R & D appropriations. Of all their outlays, an average of about 5 per cent went into basic research, about 40 per cent into applied research, and about 55 per cent into development. A majority of lab heads agreed that a laboratory of over 100 total staff constituted a minimum critical size for efficient operations. (J. Olin, "R & D Management Practices: Chemical Industry in Europe". In: *R & D Management,* Vol. 3, No. 3, Oxford, 1973, p. 127.)

innovations and discoveries. Each of these separately would have made the system only a few per cent more efficient, and only their combination sharply enhanced efficiency. None of the systems studied had been the result of a single fertile idea. Sherwin notes with regret that the organisation of research laboratories does nothing to help flourish the important figure of the "ideas generating man". Whenever the pivotal idea existed, it required an additional 5-10 almost similarly valuable ideas for its realisation, with the latter coming from various (mostly applied) fields of knowledge. Two-thirds of the knowledge required to develop a new weapons system is obtained, as Project Hindsight has clearly shown, in the process of development, with only 33 per cent being available at the time the project is started. The bulk of the scientific knowledge (80 per cent) comes from the universities, where there are groups working on contracts from the Defence Department (the discovery made by Charles Townes, for which he was awarded the Nobel Prize, is the most striking illustration of this).

The main motive factor in the work of scientists and developers was their clear awareness of practical needs. Now and again, the invention or discovery was finally embodied in a product for which it had not been earmarked, but it was always designed for a concrete objective.

Scientists, as Project Hindsight showed, themselves suggested ways of solving various problems, despite the fact that at the initial stages when the benefits were not all that obvious, the financing had to be obtained by trickery. The most headway was made in laboratories where the scientists were able to secure the financing of a new idea (up to $50,000), simply by applying to their immediate superiors.[1]

Sherwin asserted that in the definition of "research and development" the emphasis should be on "development", while research should be subordinate to the requirements of the developers. Without denying the value of basic research, it is safe to say, he wrote, that it must be reduced in volume: a small group of the most talented scientists could be allowed to engage in it. For the time being, the

[1] *Climate for Creativity*, p. 143.

bulk of basic research is second-rate and its financing amounts to a total waste of money. It is much better to have these men and their work tied in with some concrete practical problem, whereupon the research becomes more purposeful and productive. [1]

This conclusion from Project Hindsight, as the US press has also suggested, cannot be regarded as being incontestable. It was pointed out, for instance, that without the earlier basic research, neither the modern developments nor the developers with a sufficiently high qualification, who must inevitably rely on the fundamentals of science, would have existed. The advance of basic and applied research in a proportionate and dynamic equilibrium with the development of their results is an indispensable condition for a sound technical division of labour and implementation of effective scientific and technical innovations.

Information and the Professional Division of Labour

The *information function* has an especially important role to play in the division of labour in modern scientific activity.

The Soviet scientists B. M. Kedrov and S. R. Mikulinsky said: "In the past few years it has been brought out with all clarity that in the scientific, technical and economic competition the lead is not necessarily taken by countries where basic research is being carried on in greater breadth and depth, but the countries where, with a high general level of scientific development and service of scientific and technical information, the rapid application of scientific and technological achievements to production is better organised." [2]

The evolution of the social division of labour in science is entirely in accord with its evolution in social production. The development and separation of the function of scientific information exchange from the function of its direct production are as important in the

[1] Ibid., pp. 142-43.

[2] B. M. Kedrov, S. R. Mikulinsky, "Science and Modern Society". In the collection: *Science Today,* Moscow, 1969, p. 53 (in Russian).

division of scientific labour as the separation of exchange from material production was to the division of social labour as a whole. *In this context, one could draw an analogy between the role of information in the development of the production of knowledge, and of money in the development of material production.* We find Marx saying: "The relation of money to the individual appears to be purely accidental, while this relation to a thing altogether unconnected with his individuality provides the individual, because of the character of the thing, with overall domination of society, of the whole world of pleasure, work, and so on. *It is exactly as if, for instance, the finding of some stone were to give me, altogether regardless of my individuality, the mastery of all the sciences. The possession of money puts me in relation to (social) wealth in exactly the same position in which I would have been placed with respect to the sciences by the possession of the philosopher's stone.*"[1]

It is safe to say that today scientific information is in a sense this kind of philosopher's stone. In research, *exchange* of information approximates in importance the very *production* of experimental knowledge, that is, new scientific information, linking up the various stages of research and development.

Strictly speaking, science as a system of knowledge and as the process of cognition tends to "operate" only insofar as it receives information, that is, already produced knowledge, on the "in-tray", in order to produce new information (new knowledge) on the "out-tray". To such production of knowledge both the professional and the technical division of labour in science are subordinated.

Professional similarity, like dissimilarity, on matters of scientific information is of primary interest from the standpoint of the social division of labour in science. On the whole, as the record shows, the importance of information exchange in scientific activity has grown unevenly, *with a general tendency towards a growing role for secondary sources of information at the expense of the primary.* Nevertheless, it is special information that as-

[1] Karl Marx, *Grundrisse der Kritik der politischen Ökonomie (Rohentwurf) 1857-1858,* S. 133.

sumes the functions of "universal legal tender" in science. Scientists from every field of knowledge who replied to the above-mentioned questionnaire gave absolute preference to special literature as containing an analysis of the most concentrated information (from 86 per cent among technicians to 93 per cent among biologists and economists) [1]. *Verily, gratia est ex ipso fonte bibuntur aguae.*

One-half of those polled used reference journals to overcome the language barrier, and the overall atmosphere of the "information crisis" (for in some fields of scientific activity, like applied R & D, especially in engineering and technology, it is truly formidable). Reference journals, collections, express-information bulletins on the whole rank second, together with experimental research, as a channel of information, but its evaluation differs widely among scientists in various fields. It is true that reference journals are ranked on a par by mathematicians, biologists, medical men, geologists and technicians (52-57 per cent), but for chemists the figure goes up to 65.77 per cent, and for physicists down to 45.3 per cent, economists to 35.59 per cent, teachers to 19.75 per cent, and for scientists working in the humanities to 9.21 per cent. It turns out that in the various sciences the ability of information to be "packaged" is very different: attempts to present the results of research in the humanities in laconic reference form frequently deprive them of the required fullness and comprehensiveness, which actually leads to an important loss of information.

The evaluation of experimental research is even wider apart: 77.48 per cent among chemists, 62.37 per cent among biologists, 48.22 per cent among physicists, 44.44 per cent among teachers, 40.61 per cent among medical men, 32.62 per cent among geologists, 21.19 per cent among economists, 16.18 per cent among scientists in the humanities, and 8.11 per cent among mathematicians.

Workers in the technical sciences give over 52 per cent of their "votes" both for experimental research and for reference journals, a parity which will be found to

[1] This refers mostly to original or translated literature, and only 10 per cent indicate that a lack of knowledge of foreign languages hampers their work.

some extent among chemists, physicists and biologists, together with workers in the humanities, who until quite recently regarded experiments as being something alien and inaccessible. Meanwhile, geologists, medical men, economists, and mathematicians, in particular, clearly prefer information drawn from reference journals, while teachers seem to have a strong bias in favour of experiments.

Consequently, there are good grounds for the conclusion that the organisation of information services not only at technical but also at natural science institutes is now as important as experimental facilities. That is not to say, of course, that there is an evening out of the existing differences between the professions of scientists in experimental research, on the one hand, and in theoretical research, on the other. The technical division of labour between the experimentator and the theorist will apparently be felt for quite a long time to come, and its shortcomings may hamper the development of science.

It can hardly be accidental, for instance, that in contrast to the chemists, biologists and workers in the technical sciences, the physicists we polled ranked experimental research only fourth as a channel of information. Academician Kapitsa was quite right in sounding the warning about the slow-down in the influx of personnel into experimental physics, despite the fact that the need for them is growing.

The industrialisation of science and of physical experiment, in particular, has made the experimentator physicist unusually dependent on the experimental facilities and on the group of researchers, technicians and lab assistants operating them. When the tyro physicist comes to learn from his own experience that the days of the "wax-and-string" experiment have gone forever, that he has to take his place in a long queue for the particle accelerator, and that in the experiment itself and the analysis of its results a great deal does not depend on himself alone, his urge to engage in experimental research has to face a truly harsh trial.[1]

[1] In our day, dozens of men and women, each with their own special functions, are involved in the staging of a single physical experiment (*Science Today*, p. 149).

This urge, the poll shows, tends naturally to weaken where the level of industrialisation of research is lower, namely, in the biological and the chemical sciences, in particular. There, the "man at the lab table" still means a great deal and can do a lot by himself, although this does nothing to minimise the growing collective character of scientific work in this field as well. [1] This applies to the technical sciences, even if to a lesser extent, which is again confirmed by the results of our poll.

This example shows the outlines of a truly remarkable trend: the *professional* division of labour is ever more closely interlaced with the *technical* division of labour. Pedagogics becomes almost as experimental a science as physics. On the other hand, in the "space age" experiment becomes the accepted instrument in astronomy and astrophysics. Consequently, scientists in fields of knowledge wide apart begin to use similar methods and instruments of research, as will be seen from the mathematicisation of science, the spread of cybernetic and systemic-structural methods, the general use of electronic computers and various other minor mechanisms.

"In the old days," says G. N. Volkov, "the scientist's sphere of activity ranged over a complex of scientific disciplines. Later it was confined to one basic field of science, and then to one line in that field. The next step, which science is now taking, turns out to be pivotal and crucial. In present-day conditions, research into a concrete scientific problem as a rule requires the comprehensive approach and the use of conclusions and methods from a number of allied fields of knowledge." [2]

The growing influence of the comprehensive interdisciplinary approach is also having an effect on the evaluation of nonspecialised sources of information. Thus, a higher value is put on general literature by workers in the humanities (32 per cent) and teachers (28 per cent), and a lower value by mathematicians (9 per cent); teachers rate popular science writings at 17 per cent and physicists at 5.5 per cent. But I should like to draw

[1] It is also important that under the existing rules it is still much easier to obtain a scientific degree by doing work individually, instead of collectively.

[2] *The Scientific and Technical Revolution and Social Progress*, Moscow, 1972, p. 88 (in Russian).

attention not so much to this different evaluation as to the fact that despite the "information stress" fairly large sections of scientists in all the specialties without exception still draw their information from all these sources. In this instance, insufficiently profound specialisation is compensated by the broad approach, which special, to say nothing of reference, journals frequently lack.

The importance of the various channels of information declines in geometrical progression, which is most clearly evident in the technical sciences. Here, symposia and conferences (45 per cent of the "votes") are twice as popular as business trips (21 per cent), which are again twice as popular as casual meetings and conversations with other people (10 per cent). Finally, the latter are again twice as popular as the mass media (6 per cent). We find roughly the same picture in the other fields of research. Still, one could say that in all the sciences there is the sense of a real need to supplement specialised channels of information with nonspecialised, the formal with the nonformal, the systematic with the nonsystematic. The poll showed that symposia and conferences as channels of information were similarly rated by scientists in the various fields: from 45 per cent among economists to 65 per cent among mathematicians.

The assessment of the information value of expeditions and business trips also showed a trend towards interdisciplinary similarity, ranging from over 7 per cent for mathematicians and physicists to 12-13 per cent for chemists and medical men, 20-26 per cent for workers in the humanities and teachers, 29-35 per cent for economists and biologists, and 60-64 per cent for geologists. Here, we find once again that the differences in the professional division of labour in scientific activity have done nothing to upset its integrity and the common tendencies in the development of the style of work itself.

The differentiation of scientific knowledge is ever more closely interwoven with its integration not only in theory, but also in the practice of modern scientific activity. In the light of this, it is impossible not to admit the farsighted policy of those who founded the Soviet system of higher education. Back in the 1920s and 1930s, they laid emphasis on the priority growth of the network of

higher technical schools in order to supply engineers for the rapidly developing economy, while showing concern for the development of natural science and social science higher schools. At the same time, special attention was given to the teaching of the social sciences—historical, philosophical and economic—in the technical and natural science higher schools.

Under the on-going scientific and technical revolution, the higher schools in the West have had to take a similar path. Social science courses have been introduced at a number of leading higher technical schools in the USA, Britain, FRG and other countries. What is more, the question is being considered of adding a "humanities" strand to the natural science and technical disciplines. Thus, the Report of the National Academy of Sciences Physics Survey Committee in the United States on the prospects for the development of the physical sciences expressed a readiness to consider the latter as being humanitarian, because they have a contribution to make to human values, both material and spiritual. [1]

We find some confirmation of the tendency for a deepening of the technical rather than of the professional division of labour in the replies to another questionnaire circulated by *Literaturnaya Gazeta*, entitled "The 20th Century: Science and Society", from 1971 to 1973. In his reply, the well-known French mathematician, member of the Academy of Sciences of France, of the Academy of Sciences of the USSR, and of the National Academy of Sciences of the USA, Jean Leray wrote that a study of science did not at all necessarily require professional commitment. Indirect evidence of the tendency towards a synthesis of the professional division of labour by scientific disciplines with the technical division of labour by the types of research will be found in the biographies of modern scientists. Academician A. Nesmeyanov, one-time President of the USSR Academy of Sciences, a leading specialist in the chemistry of organo-elemental compounds and an organiser of Soviet science, graduated from the Physico-Mathematical Department of Moscow University in 1922. A leading US physicist and a Nobel Prize winner (who shared it with the Soviet scientists

[1] *Science News*, Vol. 102, No. 7, 1972, p. 101.

Academicians N. Basov and A. Prokhorov) for work leading to the development of lasers and masers, Charles Townes, was not a university student of the exact sciences, but specialised in linguistics and subsequently worked in other humanities, which eventually determined his approach to the problems of the exact sciences. Vice-President of the Lithuanian Academy of Sciences J. Požela also objects to the narrowing down of the individual's field of activity in the exact sciences. Considering the need to intensify attention among young people to the humanities, Academician Y. Zeldovich says that "in style, the humanitarian sciences themselves tend increasingly to approximate the exact sciences", while Academician of the Georgian Academy of Sciences V. Chavchanidze declares: "The conception of exact and inexact sciences has been hopelessly outdated, but not everyone is yet aware of this."

The professional division of labour, in a sense retreating into the background, leaves room for mutual complementarity of the technical and positional division of labour. Thus, the most qualified researchers in the experimental sciences—doctors of science, senior research associates—frequently have their junior assistants carry out experiments despite the fact that they themselves are still officially designated as experimentators. Conversely, junior research associates, even when they are theoreticians, are seldom able to have others make experimental verification of their hypotheses and so also have to perform the duties of experimentators. It is true that this depends to some extent on the state of the material facilities. [1]

What then are the material conditions for the technical and positional division of labour? One poll makes it possible to rank the amount of requirements in the various types of business machinery. The typewriter comes first with 47.38 per cent, the desk-top calculator second, with 40.65 per cent, and the duplicating machine third, with 39.34 per cent. These are followed by the telephone (31.73 per cent), the electronic computer (30.01 per cent) and, finally, the dictating machine (12.78 per cent).

[1] C. P. Snow says that the scientific revolution was inaugurated when atomic particles were first made for industrial use (C. P. Snow, *Public Affairs*, p. 131).

The data on the requirements in business machinery among those working in the technical sciences provide a median for all the other disciplines.

Professional features stand out in greater relief with respect to the mathematical business machines. The desk-top calculator and the electronic computer, at a higher level, provide an indicator of the mathematicisation of scientific knowledge.

Table III-1

Requirements in Desk-Top Calculators and Electronic Computers in Various Fields of Knowledge (per cent)

Those polled	Desk-top calculator	Electronic Computer
Biologists	50	7
Chemists	45	15
Geologists	42	15
Technicians	41	30
Physicists	39	40
Medical men	34	13
Mathematicians	28	48
Teachers	22	9
Humanitarians	5	4

A comparison of requirements in mathematical business machinery in the various fields of science has yielded an unexpected result. It turns out that the need for desk-top calculators and electronic computers is almost strictly inversely proportional. The figure for the first monotonously declines from 50 per cent among biologists down to 5 per cent among the humanitarians, while the second just as monotonously increases from 7 per cent among biologists to 48 per cent among mathematicians. Teachers turn out to be only slightly less zealous users of desk-top calculators than mathematicians, and more zealous users of electronic computers than biologists.

Against the background of the growing homogeneity of scientific activity, and the development of comprehensive

interdisciplinary research, there is an ever more pronounced tendency *towards a synthesis of the professional and the technical division of labour, which is keynoted by the latter.*

In his Report at the 25th Congress of the CPSU, L. I. Brezhnev urged the need for the continued development of theoretical research in the USSR. He said: "Fresh opportunities for fruitful general theoretical, fundamental, and applied research arise in inter-disciplinary areas, notably, in the natural and the social sciences. These should be fully used." [1] The Resolution of the 25th Congress of the CPSU speaks of the need "to ensure further development of basic and applied research in social, natural and technical sciences". [2]

While the exchange of scientific information is a necessary condition for the production of new scientific knowledge, scientific communication and regular contacts between scientists are just as necessary a condition for such exchange, for the greater the glut of the official channels of scientific information, the greater the importance that attaches to the unofficial channels, personal contacts among scientists in the first place.

Judging from the results of our poll, the technical division of labour between the stages and types of research tends to predominate over the professional division of labour among individual scientific disciplines also in the sphere of scientific communication.

Thus, there is a high interdisciplinary similarity on the optimal degree of intensity of working contacts: 62-69 per cent of physicists, chemists, mathematicians, biologists, geologists and teachers favoured occasional contacts with their colleagues; only the medical men and the humanitarians had a lower percentage, respectively 52 and 56. Individual work was preferred by 42-46 per cent of the physicists, chemists and biologists; 51-50 per cent of the economists, biologists and medical men; 59.26 per cent of the teachers and 62.65 per cent of the humanitarians, but only 38.74 per cent of the mathematicians. Regular contacts were favoured by 24.27 per cent of the

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[1] *Documents and Resolutions. XXVth Congress of the CPSU*, Moscow, 1976, pp. 87-88.

[2] Ibid., p. 231.

physicists, 23.42 per cent of the chemists, 22.59 per cent of the medical men, but only 17-18 per cent of the humanitarians, economists, geologists, biologists and mathematicians, and only 14.81 per cent of the teachers. One could well ponder over the unexpected fact that mathematicians were "good mixers" and teachers otherwise. What about those in the technical sciences? Here, 64.18 per cent voted for occasional contacts with their colleagues, which is 50 per cent more than those favouring individual work, but 200 per cent more than those favouring regular contacts. Let us bear in mind that these are engineers whose work tends especially to be expressly collective, largely predetermining the growth of "Big Science" in our day.

Perhaps this is the result of some "saturation" of such growth? Or is it the result of massive disappointment in professional contacts?

No, the answer is quite different. Replying to the question of incentives, nearly 36 per cent of those working in the technical sciences emphasised the opinion of their colleagues, which is on the same level as material incentives (40.85 per cent) and has marks that are five times as high as those given to the opinions of their immediate superiors or intimates, and 2.5 times higher than general public recognition.

The answer appears to lie in the conditions created by the current scientific and technical revolution. While investing the once purely individual efforts of the scientists with a collective character, it simultaneously intensifies stress and the urge to limit contacts in response to such stress. Thus, research engineers labour under the effect of some of the negative aspects of the inevitable nervous tension arising from their involvement in large-scale projects which are subject to a rigid timetable and entail a high responsibility for the outcome. The urge not to have too many, but not too few, contacts with one's colleagues is a natural protective reaction to the growing burden of stress. Consequently, this is an instinctive regulation of intensive contacts, a probing for a modicum of it.

Does this mean that the collective nature of work in modern science suffers some loss? Does this mean that less and less importance is being attached to contacts

with one's colleagues and to their opinions? Not at all. The opinion of one's colleagues is designated by 34-39 per cent of scientists in all fields as the most important incentive for work, with the economists and teachers rating it somewhat lower (30.61 per cent and 29.63 per cent). But the two latter groups rank the incentive as second following the satisfaction derived from the process of cognition and creativity, which gets a record number of "votes" from all fields (93-96 per cent, and only for the economists 87.71 per cent).

There is equal unanimity in evaluating the share of publications meriting recognition by specialists as the most acceptable yardstick of the productivity of creative effort (61-69 per cent). Once again the economists (54 per cent) and teachers (49 per cent) give lower marks.

People, Posts, Degrees

Consequently, while the differentiation of scientific knowledge has brought to the fore the development and deepening of the *professional* division of labour in science, the differentiation of the stages of research has raised the *technical* division of labour to a new level. At the same time, the growing collectivity of research and the consequent transition from the "Small Science" involving lone-wolf scientists to the "Big Science" of scientific organisations have given an impetus to the development of the *positional* division of scientific labour. In practice, the professional division of labour in science is closely interwoven with the technical division of labour, and the latter with the positional. But that is not the end of it.

As the professional, technical and positional division of labour in science are complexified they are combined with some elements of the demographic division of labour. These are especially characteristic for the Soviet Union, which leads in the share of women and young people among scientific workers. Here, the professional division of labour among the scientific disciplines and the technical division of labour among the scientific functions and also among the scientific posts continue to be definitive.

All of this taken together makes up a fairly intricate division of labour pattern in modern scientific activity.

Some light is shed on the contours of this picture by the results of the above-mentioned sociological study which we carried out in 1970-1971.

Let us first see the relationship between the demographic structure of the main body of the questionnaires with the positional, professional and technical division of labour in scientific activity. Of the total polled, 78.27 per cent were men, and 21.73 per cent—women. On the whole, this corresponds to the balance between the sexes among scientific workers in the USSR (61 per cent and 39 per cent), reflecting the fairly marked increase of participation by Soviet women in scientific activity.[1] The age make-up of those polled is also representative: 73.45 per cent were under 45, the most creative age in science (this is also the age of more than 80 per cent of those engaged in science and scientific services in the USSR).

Table III-2

Age Groups in Science and Scientific Services in the USSR on 1.6.1967 (per cent)*

Total	Under 25 years	25-34 years	35-44 years	45-59 years	60 years and over
100	15.6	40.4	26.2	15.9	1.9
(100)	(3.03)	(36.86)	(33.56)	(19.63)	(6.84)

* *The Economy of the USSR in 1967*, Moscow, 1968, p. 659 (in Russian). The figures in bracket show the age groups of those who replied to our questionnaire in a spontaneous (massive) sampling of the questionnaire. The share of persons under 25 years is one-fifth of their share according to statistical data, and we consider their opinions only in some cases.

[1] "One-third of Russian graduate engineers are women. It is one of our major follies that, whatever we say, we don't in reality regard women as suitable for scientific careers. We thus neatly divide our pool of potential talent by two" (C. P. Snow, op. cit., p. 45). In the USA 6 per cent of the scientists and engineers are women (*Characteristics of the National Sample of Scientists and Engineers*, No. 57, 75-333, 1974, p. 32; *The 1972 Scientist and Engineer Population, Redefined*, Vol. 1, NSF 75-319, p. 3).

These data show that men and women of young and the most productive ages constitute an absolute majority in Soviet scientific activity: the under 45 groups account for 82.2 per cent, and the under 60 for 98.1 per cent of all those engaged in science and scientific services.[1] The prevalence of young people gives scientific activity in the USSR an especially high mobility. Young people are better mixers than their elders, and in replying to our questionnaire, the following figures were obtained for "solitude and complete tranquillity" as the best approach to scientific endeavour: only 37.72 per cent of those under 25 years, 44.16 per cent from 25 to 35, 48.65 per cent from 35 to 45, 56.64 per cent from 45 to 60, and 62.65 per cent over 60. Those who favour occasional contacts with colleagues dwindle in numbers gradually down the five age groups from 65 to 53 per cent, while those who favour regular contacts drop from 26 to 19-21 per cent in the first four groups, and go up to 25 per cent among those who are over 60, which is probably due to their teaching and administrative activity. The opinion of colleagues as a creative incentive is valued most by persons between the ages of 35 and 45 (38.83 per cent), then by the 25-35 group (34.78 per cent), 45-60 group (33.60 per cent), over 60 (32.30 per cent) and least of all by those under 25 (25.44 per cent).

A person's place in the positional division of labour is determined by his or her functions, which are closely connected with the post held and the qualification level.

From the standpoint of the positional division of labour, it is important that the greatest interest in the questionnaire was displayed by leading scientific workers: 2.42 per cent of those who replied were heads of scientific establishments; 30.48 per cent were sector and laboratory heads; 22.61 per cent were senior research associates; 5.85 per cent were senior engineers; junior research associates made up 15.74 per cent; engineers 4.12 per cent; and teachers 18.16 per cent.

[1] In the United States (1972), the average age of scientists was 38 years, 5 per cent of them were under 25, 43 per cent from 25 to 39, 39 per cent from 40 to 54, 12 per cent from 55 to 64, and 3 per cent from 65 and over, which means that the under 55 groups accounted for 85 per cent, and the under 65 groups for 97 per cent (*NSF. Science Resources Studies. Highlights, July 20, 1973,* NSF 73-306, Washington, 1973).

Table III-3

Grouping by Sex, Post and Qualification of Those Who Replied to the "How Do You Feel Working?" Poll (per cent)*

Posts, degrees	Sex		Age				
	Male	Female	Under 25	25-35	35-45	45-60	Over 60
Junior research associate	62.50	37.50	8.61	64.53	21.29	4.22	0.34
Senior research associate	74.71	25.29	0.24	29.18	43.88	20.71	5.76
Engineer	67.10	32.26	23.23	60.65	12.90	1.94	0.65
Senior engineer	76.36	23.64	5.45	64.09	20.91	6.82	2.27
Laboratory head	89.09	10.73	0.44	23.65	37.17	27.57	11.17
Research institute head	93.41	6.59	—	13.19	45.05	34.07	7.69
Without degree	75.62	24.38	8.13	57.79	23.70	8.50	1.66
Candidates of science	78.02	21.83	0.25	30.46	42.50	21.53	5.17
Doctors of science	87.26	12.74	—	1.42	23.11	44.81	30.66

* *Literaturnaya Gazeta*, March 22, 1972.

That is why the data on the age structure of the leading personnel in science are characteristic: among the heads of the institutes who sent in their answers, the largest groups were from 35 to 45 years, and from 45 to 60 years (45.05 and 34.07 per cent, respectively). The heads of laboratories and sectors were somewhat younger, although, on the other hand, they also included more persons of pension age. In general, this kind of structure meets the demand for professional and human experience which leaders are expected to have, and the standards rise at every successive rung in the hierarchy. But this does not rule out the need for more active advancement of young people of both sexes to leading posts. [1]

[1] A. M. Rumyantsev, "To Those Who Enter the World of Science". In the collection: *Science Today*, Moscow, 1969, p. 31 (in Russian).

The possibilities of this are indicated, for instance, by the data on the qualification make-up: 30.71 per cent of the candidates of science polled are under the age of 35. It is true that only 1.42 per cent of those polled turned out to be doctors of science in this most promising age, and this is undoubtedly due to the complicated procedures used in certifying scientific personnel.

It is natural and even necessary for young people to start their way in science by taking orders from others, and not shunning the spadework. But if this is overdone, the positional division of labour tends to be weakened.

Among the factors which tend to lower productivity, according to 52.05 per cent of the answers, is the shortage of ancillary personnel. This is an indication of some shortcomings in the positional division of labour. When a scientist or a research engineer has to do the work of the supply department, the lab assistant, the typist or even the messenger, the productivity of research inevitably declines.

The make-up of those polled by scientific fields is highly indicative, for, with a few exceptions, it reflects the general proportions in the composition of Soviet scientific personnel: 37.05 per cent work in the technical sciences; 11.84 per cent in the humanities; 10.48 per cent in medicine; 8.22 per cent in physics; 7.50 per cent in geology; 7.24 per cent in biology; 6.28 per cent in economics; 5.90 per cent in chemistry; 2.95 per cent in mathematics; 2.15 per cent in pedagogics (see Table III-4).

Of much importance for the professional division of labour among those working in various scientific fields is the system of criteria of scientific productivity, which is based on the economic effect (the input-result ratio) obtained through the fulfilment of research projects, and in the broader sense, on the social effect, which cannot be measured in economic terms.

Let us see how those polled evaluate the economic effect as a criterion of scientific productivity. Quite naturally, economists give it the highest marks (46.61 per cent), followed by technicians (44.56 per cent), geologists (33.69 per cent), chemists (31.98 per cent), biologists (27.96 per cent), teachers (23.46 per cent), mathematicians (22.52 per cent), physicists (18.77 per cent) and medical men (13.96 per cent). Workers in

Table III-4

Distribution of Scientific Workers in the USSR by Fields in 1971

Total	*927,709*	*100 per cent*
Physico-mathematical sciences	95,272	10.3
Chemical	45,815	4.9
Biological	37,342	4.0
Geological and mineralogical	20,342	2.2
Technical	409,470	44.1
Agricultural	31,146	3.4
Historical	25,138	2.7
Economic	57,518	6.2
Philosophical	12,039	1.3
Philological	48,721	5.3
Geographical	7,242	0.8
Juridical	4,765	0.5
Pedagogics	31,283*	3.4
Medical	48,750	5.3
Pharmaceutical	1,207	0.1
Veterinary	4,300	0.5
Art criticism	12,182	1.3
Architecture	2,590	0.3

* Including 1,924 in psychology, first listed as a scientific specialty in late 1968.

Source: The Economy of the USSR in 1972.

the humanities (9.66 per cent), the product of whose work it is especially hard to express in terms of money, naturally come last. The economic effect obtained is usually connected with material incentives, and it is not surprising that material incentives are evaluated similarly, although the figures are much closer together: technicians (40.85 per cent), economists (35.59 per cent), chemists (35.14 per cent), mathematicians (32.43 per cent), physicists (31.39 per cent), medical men (28.43 per cent), geologists (25.89 per cent), teachers (25.93 per cent), workers in the humanities (24.49 per cent), and biologists (22.58 per cent).

As one would have expected, we find the opposite picture in the evaluation of social effect (which defies mea-

surement in economic terms). It gets the highest marks from workers in the humanities (42.92 per cent) and teachers (40.74 per cent), followed by economists (34.75 per cent), medical men (30.96 per cent), technicians (27.71 per cent), biologists (22.22 per cent), mathematicians (18.92 per cent), geologists (18.44 per cent), chemists (17.12 per cent), and physicists (16.83 per cent). The evaluation of an aspect of social effect like the existence of pupils and followers, that is, of a scientific school, is assessed more unanimously, from 37 per cent to 41 per cent, and only the economists have a much lower figure—29.66 per cent. On average, economic effect as a criterion of scientific productivity got 31.38 per cent of the "votes" from all the fields, and the social effect 27.71 per cent, but many more—37.42 per cent of those polled—came out for the scientific school factor. Add to this the fact that material incentives were underscored in 33.14 per cent of the questionnaires, while the chief moral inducement—satisfaction from the process of gaining knowledge and creative endeavour—got 92.77 per cent.

This gives some grounds to regard in a new perspective the tendencies in the development of the connection between scientific activity and commodity-and-money relations, between science and society taking shape at the present stage of the social division of labour.

It is characteristic in terms of professional distinctions between the scientific disciplines that the stimulating role of the opinions of intimates, who do not as a rule have any special competence, gets a lower rating where knowledge is more esoteric. Among mathematicians it comes to only 5.41 per cent, physicists 6.15 per cent, chemists 6.76 per cent, geologists 7.09 per cent, biologists 7.53 per cent, medical men 7.87 per cent, economists 9.32 per cent, workers in the humanities 10.11 per cent, and teachers 11.11 per cent. It is well known that there is more extensive exchange of opinions on pedagogical matters (for who does not, in his heart of hearts, believe himself to be a born teacher?), literature, art, history and even economics than on the natural, to say nothing of the exact sciences. But this puts scientists at a disadvantage from the standpoint of the opportunities for professional contacts. It is not surprising therefore that

mathematicians whose opportunities for such exchanges are especially limited outside the sphere of their work tend to meet their colleagues much more often than, say, teachers.

Table III-5

Evaluation of Economic and Social Effect as a Criterion of Scientific Productivity (per cent)

Specialists polled	Economic effect	Social effect
Economists	44.61	34.75
Technicians	44.65	27.71
Geologists	33.69	18.44
Chemists	31.98	17.12
Biologists	27.96	22.22
Teachers	23.46	40.74
Mathematicians	22.52	18.92
Physicists	18.77	16.83
Medical men	13.96	30.96
Workers in the humanities	9.66	42.92
Average	31.38	27.71

This is also apparently the reason why there is so much latitude in the evaluation of an incentive like broad public recognition (repute). The lowest marks here were given by mathematicians (8.11 per cent), followed by geologists (9.57 per cent), chemists (10.36 per cent), physicists (12.62 per cent), medical men (13.71 per cent), technicians (14.50 per cent), and biologists (15.05 per cent). Here the steady rise ends. Among the workers in the humanities the marks leap to 22.70 per cent, economists to 24.58 per cent, and teachers to 24.69 per cent. It is quite natural that the evaluation of the share of publications broadly accepted by the readership, as a measure of scientific productivity, goes up in the same way: from 1.80 per cent for mathematicians to 18.65 per cent for the workers in the humanities. On the other hand, the importance of the number of references to the works of a

scientist in the works of other scientists declines from something like 40 per cent among the physicists to 30-35 per cent among the chemists, mathematicians, biologists, geologists and medical men, to 19-23 per cent among workers in the humanities, economists and teachers.

There is a different evaluation in the various fields of the total number of publications, which remains one of the basic criteria of scientific productivity, with the greatest importance attached to this by chemists (28.83 per cent), workers in the humanities (25.84 per cent), biologists (22.22 per cent), medical men (20.05 per cent), economists (19.92 per cent), teachers (19.75 per cent), mathematicians (18.92 per cent), technicians (16.15 per cent), physicists (15.53 per cent), and geologists (12.77 per cent). In structuring any information models account must be taken of the professional distinctions which reflect, among other things, the different conditions for publications in the various fields of science. This applies, in particular, to the models showing the spread of scientific activity and the growth of science, extrapolating to scientific activity as a whole the trends in the growing number of publications in the leading physical and chemical journals. [1]

International Contours

The scientific and technical revolution intensifies every type of link among nations, including those in science and technology, and this adds a new dimension to the international division of labour in science.

However, at present this process is running very unevenly. One author says: "The whole world is the arena in which the scientific and technical revolution has been under way, but its peculiarity as a worldwide process consists in the fact that it has actively unfolded chiefly in the industrialised socialist and capitalist countries, with all the specific features inherent in the two opposite social systems." [2]

[1] See, Derek J. de Solla Price, *Nations Can Publish or Perish*, New York, 1969.

[2] G. Y. Skorov, *Questions in the Development of Science and Technology in the Third World*, Moscow, 1973, p. 5 (in Russian).

More than 94 per cent of the world's scientists and engineers in R & D in 1972 were employed in North America, Europe and the Soviet Union, with an average of one researcher per 460 inhabitants, as compared with 35,000 for Africa.

The USA has been spending more on R & D than other Western countries, an estimated $35.2 billion a year in 1975. But the share of these outlays in its GNP dropped from 2.9 per cent in 1965 to 2.3 per cent in 1975, with the share of the federal administration declining, respectively, from 1.9 per cent to 1.1 per cent. The share of the federal budget represented by R & D programmes dropped from 12.6 per cent in 1965 to 6.6 per cent in 1975. [1]

Available estimates show that outlays on scientific activity in the developing countries come to less than 1 per cent of the total of such outlays by all the countries of the world.

The current contradictions within the international division of labour in scientific activity have left their mark on the technical and positional division of labour in science.

The average scientist or engineer usually works as a member of some research group with a number of colleagues and with the assistance of one or several technicians. In the industrialised countries, the proportions of technicians to scientists and research engineers may be as high as 4 : 2, whereas in the developing countries 6 or 7 scientists may have to make do with the services of one technician, who alone has to handle the technical problems of design and fulfilment of research programmes.

Although the brain drain has become somewhat less intensive because of the worsening job situation for scientists in the USA, the process still is important for the developing countries seeking to build up their own potential in science and technology. The number of highly skilled personnel emigrating from the developing to

[1] *Federal Funds for Research, Development, and Other Scientific Activities. Fiscal Years 1973, 1974 and 1975,* NSF 74-320, Vol. XXIII, p. VII; *National Patterns. R & D Resources, Funds & Manpower in the United States. 1957-1976,* NSF 76-310, p. 13.

the industrialised countries is estimated to total tens of thousands a year, which is considerably more than the influx of technical aid personnel from the developed to the developing countries.

But that is not the whole story. A veiled brain drain, in the form of exploitation of intellectual resources on the spot, has been acquiring ever larger proportions.

Through the "aid" system in training personnel (scholarships, courses, assignment of teachers, and so on) the United States has been shaping the content of research, orienting it upon the subproblems facing US science, instead of regional problems. And here the escape of the best minds is only the tip of the iceberg, for the rest are also working for the United States (spending their countries' resources). Most of the scientists are "TV-managed" from US laboratories, and their research projects are very frequently geared to solving some of the problems being tackled in the USA. It turns out to be profitable for the United States to build and equip research centres as gifts under "aid" agreements because these centres are then entered on the country's books and financed by it, while the scientific direction comes from the United States. This is being most widely practised by the multinational monopolies, writes a Soviet student of science, S. G. Kara-Murza.

According to the Yearbook of International Organisations in 1970 there were nearly 8,000 companies with their own subsidiaries in at least 3 other countries, and more than one-half of these multinational companies were based in the United States or Britain.

By the early 1970s, the value of the goods and services sold by the international monopolies came to one-third of the GNP of all the capitalist countries taken together. In 1972, the foreign subsidiaries of the multinational and transnational monopolies turned out manufactured goods valued at $370 billion, which is more than the whole of the capitalist countries' exports. The financial strength of these monopolies will be seen from the fact that their liquid assets are many times larger than the foreign exchange reserves of all the central banks of the capitalist countries.

Academician N. N. Inozemtsev says: "The spreading activity of the international monopolies, which inevitably

clash with the economic policies of the states, and with their efforts in programming their economy, is one of the most visual indications of the limited potentialities of present-day state-monopoly regulation." [1]

The activity of the international monopolies has been steadily moving beyond the control of individual states and governments in the capitalist world. At the very start of the current decade, 680 monopolies (or 8.5 per cent of the total) had ten or more foreign subsidiaries. The annual turnover of General Motors in 1969 was, at $24.3 billion, greater than the GNP of either Switzerland or South Africa; that of Standard Oil of New Jersey in 1970 ($16.5 billion) was larger than the GNP of Denmark; that of Ford greater than the Austrian GNP, and Royal Dutch-Shell's turnover was larger than the GNP of the Philippines. [2]

Many national firms, says a UNESCO report, carry on their R & D on an international basis. Thus, IBM has seven of its 19 research laboratories in Europe; Shell has 8 laboratories in Britain, 3 in the Netherlands, 2 in France, one each in the FRG, Japan and Canada, and 8 in the United States. The R & D of these laboratories frequently make up an important element of the national effort, and this applies especially to the highly competitive and concentrated field of electronic computers, where the multinational companies are prominent in a country's industrial sector (Canada, Netherlands).

The multinational companies could have an important role to play in transferring technology from one country to another, especially from the industrialised to the developing countries, but that is far from being so.

Many developing countries spend more on patents, licences, know-how and so on than on their own R & D. In 1970, Sri Lanka, for instance, spent 0.5 per cent of its GNP on these forms of technology transfer, and only 0.2 per cent on its own R & D; in 1965, the figures for Nigeria were, respectively, 0.8 per cent and 0.5 per cent. A UNCTAD report estimated that at the end of the 1960s the developing countries were spending on average an

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[1] N. N. Inozemtsev, "Capitalism in the 1970s: Sharpening Contradictions", *Pravda,* August 20, 1974.

[2] *Science and Human Needs,* Part III, p. 242.

annual sum equivalent to some five per cent of their exports on technology transfer, and that this figure was increasing at an average rate of 20 per cent a year. Excluding the major oil exporting countries, the figure was equivalent to two-fifths of the debt-servicing costs of the developing countries, and about 56 per cent of the flow of direct foreign investment to developing countries (including reinvested earnings).[1]

Thus, just before the overthrow of the Popular Unity government in Chile, 50 per cent of the foreign subsidiaries had a monopoly or duopoly position on the domestic market, while 36.4 per cent of the others had oligopoly positions, and only 13.6 per cent controlled less than 25 per cent of the market.[2] Of the 175 contracts they had concluded, 98 contained clauses on quality control by the licenser, 45—clauses on control of the volume of sales, and 27—clauses on control of the volume of production.

According to Charles Cooper, "technology supplies are concerned with the commercial advantages they can obtain through the transfer operation. There would be no problem about this if the pursuit of commercial advantage by the suppliers led to results which were in line with the economic and social requirements of the developing countries. There is, however, a good deal of evidence that this kind of coincidence is rare. Particularly in the case of indirect transfers, the developing countries face a contradiction: they need the technology and the capabilities which the supplying companies possess, but the terms on which they can get hold of it may be disadvantageous for economic and social development."[3]

Consequently, the international division of labour is practised by the multinational monopolies in a form which does nothing to help the developing countries develop their scientific and technical potential or raise their own scientific, technical or educational standards.

According to the UNESCO report, multinational companies based mainly in the United States and Britain

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[1] *Science and Human Needs,* Part III, p. 251.
[2] Ibid., pp. 252-53.
[3] Ibid., pp. 253-54.

have also been exploiting the intellectual resources of the industrialised countries. Making use of some of their advantages in financing and organisation, US corporations have made use of the bulk of the information obtained by applied science in Europe before the hosts managed to do so. To facilitate the extraction of information over the past few years, they have extensively practised the establishment of their own laboratories in Europe (the smoother communications probably offer a weightier reason than payroll economies). Through these laboratories (whose employees continue to be a part of the European scientific community) intellectual and creative resources are being funnelled from Europe to the United States.

In the fundamental sciences, the leading laboratories in the USA seek to involve the best scientists from Europe in their own operations, so isolating them from the scientific community of their own countries. A study of 100 US corporations engaged in R & D in Europe, carried out by the Stanford Research Institute, shows that most of them spend less than 4 per cent of their research budgets in Europe, their main aim in most cases being access to the European scientific community and through it to research going on in Europe. IBM offers an example of a corporation with a deliberate policy of internationalising the resources of its research activity. The manufacture of computers calls for large R & D outlays, and IBM itself has spent up to $5 billion to develop its IBM-360 series (IBM has neither confirmed nor denied the figure). Today, computer makers have to spend from $25 million to $50 million a year on research in order to maintain their competitiveness on the world market. Assuming that this comes to 5 per cent of their turnover, the annual turnover of such companies should come to between $500 million and $1 billion. Actually, in 1972 IBM's turnover totalled $9,532 million, and its outlays on R & D that year came to $676 million, of which $50 million went into research alone. The scale of the enterprise is one of the reasons why IBM has been able to maintain such strong positions on the world markets (Britain and Japan are the only major countries where IBM's share of the computer market in 1968 was under 50 per cent). In Europe, IBM has 7 laboratories: a basic research laboratory in Zurich, and development laboratories

in the FRG, Austria, the United Kingdom, France, Sweden and the Netherlands. Each country specialises in a definite range of computers. While IBM subsidiaries in the various countries may share out research subcontracts among themselves, the bulk of the R & D funds comes directly from the parent company in New York, which has tight control of overall research policy. In Sweden and Austria, IBM has recruited many capable scientists and engineers for its work on computers.

An IBM executive has admitted, for example, that "people sometimes feel we are exploiting their country's brains and talents in the same way as a mining company exploits its natural resources". [1]

This may be one of the reasons why in the second half of the 1960s many Western countries began to cut back their share of outlays on international scientific and technical programmes. Thus, the FRG's contribution to international governmental organisations for science and technology dropped from 13.5 per cent of the Federal R & D budget in 1966 to 7 per cent in 1970; in Italy the figures were, respectively, 24.2 per cent and 12.8 per cent, and in Britain the decline was from 8.2 per cent in 1965 to 3.5 per cent in 1970. In France and some other countries, the cut-back was not as spectacular, while in the smaller countries the outlays have even continued to grow. The overall reduction was directly connected with the cuts effected in the budget of Euratom and ELDO (European Space Vehicle Launcher Development Organisation) which together with ESRO (European Space Research Organisation) and CERN (European Organisation for Nuclear Research) took up 95 per cent of the resources of 18 major international scientific and technical organisations in 1970. [2]

Meanwhile, the advantages of international scientific and technical programmes are obvious and these have been well demonstrated by various forms of division of labour in science and technology among the socialist countries both on a bilateral and multilateral basis. The USSR Academy of Sciences has engaged in fruitful co-

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[1] *Science and Human Needs,* Part III, pp. 245, 248.
[2] Ibid., p. 191.

operation with the academies of sciences in other socialist countries under bilateral agreements on scientific exchanges. Within the CMEA framework, a plan is being implemented for the coordination of scientific and technical research projects of mutual interest by the CMEA countries. In accordance with the Comprehensive Programme for the Further Extension and Improvement of Cooperation and the Development of Socialist Economic Integration by the CMEA Member Countries, they have worked to raise the division of labour in science and technology to a higher level. Together with the coordination of R & D plans and implementation of various joint projects, more and more problem laboratories, research institutes and centres are being set up on a multilateral basis. There is growing exchange of scientific, technical and design documents and information, and joint programmes are being successfully fulfilled. Thus, a joint research project realised by scientists from the German Democratic Republic and Czechoslovakia to obtain food protein from petroleum helped Czechoslovakia to save about 6 million korunas (roughly $417,827) and the GDR, 3 million marks in payroll costs. [1] In 1975, Czechoslovakia's national income was 132 per cent on 1970. [2]

Relying on the experience of the USSR, the socialist community countries have started to set up an integrated network of multinational scientific centres, which is based on a unified system of scientific and technical information already operating within the CMEA framework, and which will be able to cope with programmes of any complexity or labour intensiveness. This kind of programmes are required for the elaboration of 13 basic lines and the solution of more than 100 key scientific and technical problems, as determined for the CMEA countries' cooperation in the 1976-1980 period. This explains why the guidance in the effort to fulfil the Comprehensive Programme is being provided, alongside dozens of coordinating centres and scientific coordinating councils, by a number of international groups of scientists and scientific and production associations. [3] Thus, in order to tackle the problem

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[1] Ibid., p. 193.
[2] *The Economy of the USSR in 1975*, p. 122.
[3] *Science Today*, Moscow, 1974, pp. 40-42 (in Russian).

of Research into Organisational Administration, Cybernetics and Operations Research an international group of scientists under the Institute of Control Sciences (Automation and Telemechanics) of the USSR Academy of Sciences in Moscow has been set up alongside the International Scientific Coordination Council. The former deals with the elaboration of models of economic systems control at various levels with an eye to their interaction, the principles of controlling man-machine complexes, and the solution of problems arising with the use of computer techniques and hardware in the area of management. Within the framework of this collective, which has the status of an independent international organisation, specialists from the CMEA countries have joined together in research and development in this basic scientific and technical problem. [1]

Today, nearly 800 research institutes, design and development organisations and enterprises in the Soviet Union are engaged in joint projects with about 900 organisations in other socialist countries, which are together working on something like 2,300 projects that are of primary importance in accelerating scientific and technical progress.

Project Revertaza has provided visual evidence of the effectiveness of the project for organising research with the most extensive interinstitutional, interdepartmental and international scientific cooperation. Important experimental evidence of RNA reverse transcription has been obtained at laboratories in Moscow, Kiev, Riga, Berlin and Prague. It has also transpired that this work opens up new horizons not only for new basic research in molecular biology, but also for the practical application of the results obtained in the most important areas. Project Revertaza paves the way for a purposeful and effective drive against cancerous diseases. The mastering of reverse transcription also opens up prospects for genetic engineering, ranging from the synthesis of genetic material in accordance with natural matrixes, to the transformation of cellular genomes through the implantation within them of artificially fabricated DNA molecules.

The success of science projects shows that the project

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[1] *Science Today*, Moscow, 1973, pp. 46-47 (in Russian).

form of organising research is one of the most promising in scientific cooperation, above all for academies of sciences, universities and other basic research institutions in the socialist countries. Its advantages lie in the fact that it most fully meets the tendencies towards self-organisation inherent in this category of research and most fully taps the potentialities of science as a self-organising system.

With time, scientific research among the socialist countries in atomic energy, providing the infrastructure for economic integration, has developed into scientific and technical cooperation, and this, for its part, has grown into scientific and production cooperation. The work done by the Joint Nuclear Research Institute at Dubna in the USSR over some 15 years paved the way for the establishment in 1972 of the first international economic association, Interatominstrument, by six CMEA countries engaged in cooperation in nuclear technology and instrument-making. This provided the basis for the subsequent establishment of the Interatomenergo economic association, which has helped to cooperate the countries' technical efforts in the design, construction and servicing of atomic electric power stations in the USSR, the GDR and Czechoslovakia, and then in Bulgaria, Hungary, Rumania and Poland.

The integration of the socialist countries' scientific and technical potentials, together with the integration of their personnel, has increasingly involved their technical element which is closely connected with the personnel element. Many examples of this will be found, for instance, in the implementation of the long-term and comprehensive Interkosmos programme, where the central element is the man-machine system. At an international exposition, Public Health-74, one of the exhibits on show was a "biomonitor" developed by a group of specialists from the CMEA countries, this being a control post to monitor the condition of gravely ill patients, and automatically to control the functioning of the heart, and the level of temperature, blood pressure and breathing. In a sense, this is a model of the future integrated system for the collection and processing of scientific data being developed by the CMEA countries on the basis of their *Ryad* electronic computer series.

In his Report at the 25th Congress of the CPSU, L. I. Brezhnev considered the development of the CMEA countries' cooperation and said that the effort to fulfil the Comprehensive Programme has led to a marked deepening of their economic interaction and a growing mutual complementarity of their national economies, so yielding considerable benefits to each of them.[1]

This natural line of development reveals the operation of the external complement principle, which was discussed above. Gödel's Incompleteness Theorem suggests that the scale of the state could well fall short of that required for realising all the potentials of an automated control system. The state, especially a small or medium-size one, is able fully to realise such potentialities only within a metasystem of friendly countries consistently implementing the international division of labour and internationalisation of production.

In the past few years, there has also been a marked development of division of labour and cooperation in the scientific and technical field between the socialist and the capitalist countries, including that between the USSR and the USA. Their cooperation ranges over an ever broader spectrum of problems, from efforts to combat cardiovascular and cancerous diseases to the mastery of intranuclear energy and protection of the environment. Especially tangible advantages accrue from the division of labour between the Soviet Union and the United States in the exceptionally intricate and costly area of space research. In the long run, there could also be a division of labour between the two countries in some production research (like automobile-making) and in the extension of scientific and technical assistance to third countries.

The State Committee of the USSR Council of Ministers for Science and Technology has concluded agreements on scientific and technical cooperation with scores of corporations in the United States, among them General Electric, General Dynamics, Monsanto Chemical Co., Occidental Petroleum, and Kaiser Steel Corporation. The American side is as interested as the Soviet side in further developing such cooperation. Thus, Texas Utili-

[1] *Documents and Resolutions, XXVth Congress of the CPSU*, p. 12.

ties Services has gained much benefit from the acquisition of a Soviet licence for the technology of gasifying brown coal deposits which abound in Texas. Soviet Belarus tractors, Lada cars, bicycles and many other manufactured goods are popular in other countries.

Mutually advantageous scientific and technical cooperation has been successfully developing between the USSR and other socialist countries, and France, Britain, the FRG, Italy, Belgium, Japan, Sweden, Finland and other countries.

Cooperation between the industrialised and the developing countries seeking to accelerate the development of their productive forces opens a broad field for the international division of labour in science and technology.

There are now more than 300 international agencies engaged in special scientific and technical activity, and almost every major international governmental organisation has important powers in this field. In the recent period, outlays on international activity for the industrialised countries have averaged from 5 per cent to 15 per cent of their research budgets.

The International Council of Scientific Unions is the major but not the only organisation coordinating scientific activity on an international level. Similar functions are also exercised by the International Council of Medical Sciences, the World Federation of Engineering Organisations, the International Union for the Conservation of Nature and Natural Resources, the International Astronautical Federation, and the World Energy Conference, each of which has an important role to play in coordinating activity in its field. The UNESCO report says that "every international governmental organisation has at least one counterpart in the NGO world". Thus, 150 NGO's, for example, "were present as observers at the UN Conference on the Human Environment held at Stockholm in June 1972".[1]

Under the current scientific and technical revolution, the social division of labour is entering upon a new important stage.

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[1] *Science and Human Needs*, Part III, pp. 187, 200, 201.

The scientific transformation of the whole of social production helps dialectically to "transcend" the fundamental contradictions arising in the process of the steady differentiation of the various spheres of human labour activity. From the technico-economic aspect, the development of scientific activity as a leading sphere of spiritual production, reflecting the logic of science's transformation into the leading productive force of society, ushers in a situation in which the process of differentiation between mental and manual labour is paralleled by a growing process of their integration. The differentiation and integration of labour functions within scientific activity itself tend to run in the same direction, and here the evolution has ever more clearly revealed the general regularities connected above all with information exchange and, in particular, with the separation of the function of information exchange from the function of generating scientific information.

Meanwhile, within the professional division of labour the processes of integration have surmounted the processes of differentiation, while the professional division of labour has been ever more closely interwoven with the technical division of labour. A strong impulse to these processes has come from the development of interdisciplinary and intersectoral research programmes.

The international division of labour in scientific activity acquires ever greater importance. Meeting the requirements of the complementarity principle, its scale has rapidly extended and its forms have become ever more diverse. This is promoted by the international detente and the swing away from the cold war to lasting peace, and to economic, scientific and technical cooperation.

Chapter Four

Scientific Network

In accordance with the external complementarity principle, the division of labour within scientific collectives is supplemented with a division of labour between them, between the institutions of science and the agencies directing scientific activity. Both on the micro- and macrolevel, the division of labour is an important premise for its cooperation and for boosting the productivity of science.

Alongside the micro- and macrolevels, a UNESCO survey of national scientific policy in the European countries also contains a characteristic of a third, intermediate level, the sectoral level. Depending on the country, the various "sectors" are delimited to: the scientific disciplines, the productive sectors of the economy, types of research, R & D sectors of performance (higher education, government institutions, etc.), and certain research programmes of national interest. As a result, the overall picture of the intermediate sectoral level turns out to be excessively fragmented and lacking in coherence.

This can be made good, I think, by considering the elements of the sectoral level as being elements of an overall system, the scientific network. Resting on the information and communication infrastructure, the scientific network helps to link up not only the various cells of scientific activity at the microlevel, but also each of these with the macrolevel. As such, the scientific network operates as a kind of transfer mechanism for scientific and

technical progress, both along the vertical, from the origination of a new idea to its realisation, and along the horizontal, helping to spread new ideas from one sector to another.

Transfer of New Ideas: TV Model

The spread of scientific and technical progress is a process by means of which science and technology permeates the various types of human activity and systematic rational knowledge obtained by one institute or group of researchers is embodied in a mode of production of knowledge or objects by other institutes or groups. "The productive development of society entails not only a growth of scientific power but also of the scale on which it has already been laid down as fixed capital, the scope and breadth of its realisation and its comprehension of the whole totality of production."[1]

This conduces either to a conversion of fundamental scientific knowledge into technology or the adaptation of existing technology to new methods and forms of use. In the first instance, we have the *vertical type of technology transfer* from the more general to the more specific. In the second, it is the *horizontal type of technology transfer*, which is equally important. In production practice we find a mixed type of technology transfer which has developed spontaneously.

It is believed that in the United States organisation both by government agencies and in industry is designed primarily for vertical technology transfer. Some shifts towards horizontal transfer were in evidence with the establishment of the Atomic Energy Commission and the National Aeronautics and Space Administration (NASA). Another step in this direction was the conversion of the National Science Foundation into a centre for coordinating not only basic but also applied research. Horizontal technology transfer, according to Harvey Brooks, may be promoted by basic and academic research by specialised agencies, and the pooling of the efforts of institutions receiving government assistance, with the maintenance

[1] Karl Marx, *Grundrisse der Kritik der politischen Ökonomie (Rohentwurf) 1857-1858*, S. 636.

of an equilibrium between various programmes and also between the individual performers and institutions.

The basic mechanisms underlying both horizontal and vertical technology transfer consist in the transfer of men between various fields of science and technology and from science to technology, and entrepreneurial activity in the broad sense of the word, including the establishment of new organisations; the publication and dissemination of scientific and technical literature, the activity of professional societies, all manner of personal contacts, scientific and technical conferences, symposia, and so on.[1] This also includes interaction between the supplier and the consumer, between the developer and his client, programmes for raising educational and skill standards, scientific and technical consultations, the sale of patents and know-how, and the organisation of marketing and technical services.

US scientists who have analysed the obscure problem of communication between scientists and practical engineers in the United States have obtained the following results on the sources of scientific ideas and information.

Table IV-1

Basic Sources of Information for 50 Polled Theoretical Scientists in the USA (percentage)

Regular reading of journals	30.4
Scientific reports and extracts from these	10.9
Authors' reprints	5.8
Reference articles and bibliographies	6.4
Compendia	4.3
Casual conversations	22.6
Information from colleagues (by request)	8.1
Other sources	11.5

Consequently, nearly 58 per cent of the ideas and information comes from scientific writings and the rest mostly from personal contacts. Practical engineers obtain only 8 per cent of their information and ideas from literature, 33 per cent from suppliers of new equipment and the

[1] Harvey Brooks, *The Government of Science,* pp. 254-74.

rest, from informal contacts, experience of predecessors and their own observations and experiments. Let us note the characteristically high information role of personal contacts in US scientific activity, as theoretical scientists and practical engineers both report.

Every innovation evidently begins with the emergence of a new and promising scientific idea or technical invention, with only the major ideas and inventions usually providing an impulse for innovation. The author of the idea then goes on to advance it at various speeds and with varying success from one phase of development and approbation to another, until it is engineered and applied in production. This is the crucial though not the final phase of innovation, for if its "potential energy" is to become "kinetic" with a minimum of loss, it should be applied as broadly as possible beyond the limits of the given industry or region, a process which may be either spontaneous or organised. So, the share of conversations among theoretical scientists in the United States as a source of information (Table IV-1) turns out to be twice as large as it is among those polled by *Literaturnaya Gazeta* in Moscow (which involved not only theoreticians, but also those engaged in other types of scientific activity).

The normative enactments effective in the USSR provide for the need and possibility of the most rapid transfer of innovations. Thus, the Statute on Discoveries, Inventions and Rationalising Proposals, approved by Decree No. 584 of the USSR Council of Ministers on August 21, 1973, says in this respect: "The State Committee of the USSR Council of Ministers for Inventions and Discoveries shall inform the ministries and departments concerned of registered discoveries for the purpose of making extensive use of these in the economy.

"Concerning discoveries which are of applied importance, the State Committee of the USSR Council of Ministers for Inventions and Discoveries, together with the USSR Academy of Sciences, the Academies of Sciences of the Union Republics, the sectoral academies and the ministries and departments concerned shall present recommendations for the use of these discoveries to the State Committee of the USSR Council of Ministers for Science and Technology, which shall examine these with-

in a period of three months and shall determine the procedure for using the recommended discoveries in the economy."[1]

The State Committee of the USSR Council of Ministers for Inventions and Discoveries takes similar measures to accelerate the use of inventions in the economy.

Whenever necessary, the Committee may request findings on applications for the issue of author's certificates to establish the possibility of using the invention from competent enterprises, organisations and establishments, which have the duty to present such findings free of charge within two months of the receipt of the request.[2]

There is also a provision for accelerating the use of rationalising proposals.

Applications for rationalising proposals must be examined and a decision adopted at the enterprise, organisation or establishment within a period of 15 days, and in ministries or departments within a period of 45 days of their receipt. Within these periods, the author must be informed either that his rationalising proposal has been accepted and adopted for use, or that the proposal must be put to an experimental test, or rejected with a statement of the motives for the rejection.

In the event of an experimental test, the author must be informed on the decision taken within 15 days of the end of the experimental test. [3]

Consequently, all types of scientific and technical innovations—from fundamental discoveries to rationalising proposals—become the object of Soviet law from the moment of their origination, and this is designed to promote the utmost acceleration of scientific and technical innovations in the country. In the socialist state, the measures which follow are strictly planned.

Ministries, departments, enterprises, organisations and establishments make a selection of the inventions and rationalising proposals on the strength of the material of the State Committee of the USSR Council of Ministers for Inventions and Discoveries, and the all-Union and

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[1] *Statute on Discoveries, Inventions and Rationalising Proposals,* Moscow, 1973, pp. 5-6 (in Russian).

[2] Ibid.

[3] Ibid., p. 19.

sectoral agencies of scientific and technical information and other information (including patent) material, and take decisions on their use in a planned manner.

Ministries and departments inform the Committee about the inventions adopted for use within their system. [1]

The rapid pace of scientific and technical and also of socio-economic and political change characterising the current scientific and technical revolution makes scientific activity and its organisation highly dynamic. While its traditional forms like universities, scientific societies and academies have centuries behind them, research institutes originated no more than a few decades ago. However, their administrative framework turns out to be too rigid and inadequate in face of the newly emergent problems and the rapid succession of scientific orientations which as a rule require the marshalling of the efforts of specialists in the most diverse fields employed in various organisations.

Thousands of men and women who have to change their place of work and domicile are frequently brought together within the framework of complex "Big Science" projects and programmes. Geographically, the scientific activity, once concentrated in a handful of big cities, has been spreading and frequently covers more than one country. There is a rapid growth in the number of "science cities", which are major complex scientific centres where the main employment of those who work is participation in the production of knowledge.

The growth of scientific centres is one of the most visual and essential expressions of the current scientific and technical revolution. Such centres, as a rule, combine the functions of training scientific personnel, of research, development, engineering and sale of the results obtained in general.

The existence of scientific centres, science cities, especially those grouped round basic research establishments, has introduced a new element not only into society's scientific and technical development but also into its social development. It would perhaps be no exaggera-

[1] *Statute on Discoveries, Inventions and Rationalising Proposals*, p. 37.

tion to compare the role of science cities in the society of the foreseeable future with the role of the medieval urban communes which concentrated the most mobile elements of the productive forces and which gave an impetus to the acceleration of the historical process as a whole.[1]

Scientific zones in big ancient cities have a similar role to play.

The dynamic of scientific and technical innovation may be likened to the flow of a stream of electrons in the electron tube. In order to improve the quality of the picture in modern TV sets, designers seek simultaneously to reduce the length of the picture tube (that is, the distance the electrons have to run from the cathode to the anode) and to increase the area of the screen. Similarly, the faster innovation system has a two-fold task to tackle: to reduce to the utmost the "run" from the origination of ideas to their embodiment, while increasing to the utmost the "area" of their realisation. That is the problem the scientific network has to solve. Although the functioning efficiency of the scientific network frequently leaves much to be desired, the closest interdependence among its cells appears to be imperative. Thus, the branch of a scientific discipline like chemistry does not, in fact, function separately from the economic sectoral branch (the chemical industry, agrochemistry, and so on), from the sector of basic research, applied R & D, the sectors of academic and nonacademic science, and so on. That is why, the scientific network has by rights a niche between the micro- and macrolevels and has an integrative function to perform.

The collective character of modern scientific activity is expressed not only in the need to cooperate the efforts of individual researchers within the scientific organisation but also to cooperate and coordinate the efforts of individual organisations. In virtue of this necessity, none of these exists by itself but only as a cell of the scientific organisation network. As a whole, the scientific network constitutes a metasystem, as it were, providing an exter-

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[1] V. V. Stoklitskaya-Tereshkovich, *Basic Problems in the History of the Medieval City of the 10th-15th Centuries,* Moscow, 1960 (in Russian).

nal complement for each of its individual elements. It is within and through the network that each realises its vital function and its reproduction within the framework of the social division of labour, thereby reproducing on an extended basis the diversity of scientific activity as a whole, which is so crucial for its successful development. At the same time, the network metasystem supports this diversity within reasonable bounds, limiting it wherever it tends to be counter-productive and harmful, so that the lame-duck scientific organisations may be taken over by more viable and promising ones or have their structure modified and their leadership strengthened. The conditions in which the scientific network takes shape and develops depend on the character of the socio-economic system within whose framework it functions.

US Science Centres

There are now a spontaneous and a conscious way of shaping and developing the scientific centre network to meet various types of science policy. The former is characteristic of the evolution of "scientific complexes" in the USA. These are based on the existence in a given area of first-rate universities or colleges capable of attracting highly skilled and vigorous specialists trained in new and promising lines of research, and also on the availability of adequate financing and of an "incubator place" in which research institutes and firms of the complex could start their activity. In addition, they must have conditions for normal growth, including natural conditions, an infrastructure, acceptable costs of business operations, living conditions no worse than those in the big cities, and a highly developed scientific, technical and cultural activity.

All these conditions and requirements are variously met by the areas in which US scientific complexes have emerged.

One widespread line of practical activity is the establishment of a new business on the basis of a scientific discovery or technical invention. To make its realisation profitable, new scientific and technical firms are set up or new firms spin off from existing laboratories or com-

panies. It is perhaps no accident that "spin-off" is a term borrowed from Air Force jargon.

A distinction is made between the old and new forms of spin-off. The former is in line with the established US tradition of individual technical enterprise inaugurated in the early 19th century by Alexis Tocqueville and represented by Thomas Alva Edison, Eli Whitney, Samuel Morse, Charles Goodyear, and Alexander Graham Bell, among others. Among contemporary continuators of this tradition are men like Jacob Rabinow, the irrepressible President of the Rabinow Electronics Co. of Rockville, Maryland, who holds 113 patents. [1]

The latter and latest form of spin-off involves enterprise not just on the basis of technical versatility, but solid scientific knowledge, and is epitomised by Howard Aiken of Harvard University, who designed one of the first Marc-1 digital machines and subsequently headed the Howard Aiken Industries, Incorporated with an annual turnover of $8 million. But lately spin-off tends to assume a group character and tends to be phased in. A peculiar instance of the "multitudinous spin-off" is offered by the history of the American Research and Development Corporation, a company for the production of new scientific and technical companies.

Such companies naturally appeared above all in the most science-and-technology intensive industries with 25 and more scientists and engineers engaged in R & D per 1,000 persons employed, and with 4 or more per cent of R & D-oriented sales.

By means of the well-adjusted mechanism of spontaneous scientific and technical establishments, the teachers and graduates of only one institute, the Massachusetts Institute of Technology, founded over 75 radio-electronic and other companies. The barriers normally separating R & D innovations from engineering are overcome in the United States through a combination in business ventures of ideas, the capital required to realise them and the necessary industrial capacities.

One Soviet economist, A. Y. Shpirt, says that "the growing role of science in the economic and social life of the capitalist countries has caused definite shifts in the

[1] *Fortune*, August 1964, p. 164.

territorial location of the productive forces. Thus, the level of concentration of research above that of production and manpower has led to the establishment of scientific and production centres. The nucleus of the latter consists of large research establishments round which the latest industries emerge." [1] This process has been circumstantially examined by Professor V. V. Zubchaninov in his writings on the science-production complex in the capitalist countries. [2]

The "industry of discoveries" in the narrow sense here tends to coalesce with the "industry of discoveries" in the broad sense of the word. [3]

Firms with radioelectronic or other rapidly growing "science-intensive" business may be said to "reproduce by division" with the use of "spin-off" methods. The spin-off usually starts with the university or industrial laboratory, as the researcher usually moves along with his product from the research stage to the stage of engineering. This does much to accelerate the realisation of scientific and technical achievements. Some corporations have set records in this field, like Raytheon near Boston, which by the mid-1960s had spun-off 25 firms.

Successful spin-off depends on a good knowledge of the market, adequate financing, high product quality, R & D contracts, a favourable environment, new equipment, or—in the absence of any of these conditions—merger with a big corporation. It takes an average of five years to show whether or not the spin-off is a success.

At any rate, spin-off, whatever its origin, is the leading and basic factor in the formation and development of scientific and production complexes. In other words, commercial realisation of R & D achievements is the main basis for ploughing them into production within

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[1] A. Y. Shpirt, *The Scientific and Technical Revolution and the Developing Countries of Asia and Africa,* Moscow, 1970, pp. 19-20 (in Russian).

[2] See V. V. Zubchaninov, *Scientific Activity and Technical Progress in the Leading Capitalist Countries,* Moscow, 1976 (in Russian).

[3] *Time,* August 14, 1964, pp. 60-61; Y. Sheinin, *Science and Militarism in the United States. The Scientific and Technical Revolution in the Military Field and the Emergence of Premises for the Crisis of Militarism,* Moscow, 1963 (in Russian).

the framework of functional systems and complexes which tend to proliferate in boom time round electronic "black boxes". In one such period, the journal of the Harvard School of Business wrote: "Spin-offs ... can be the important first step in what may develop into a chain reaction. They help set in motion the forces which tend to attract research-based new industry."[1]

In organisational terms, this spontaneous formation of scientific and technical centres deserves serious attention.

But there is also the politico-economic aspect, namely, the inevitable limitations in realising new ideas by means of spin-off set by the capitalist economy and private enterprise.

This aspect was brought out by the well-known US mathematician and cyberneticist Norbert Wiener, who in his autobiographical book remarks on the conservative streak in the character of the founder of Howard Aiken Industries, who refused to instal an electronic device in the calculating machine he invented instead of the much slower mechanical relay. Wiener adds: "Yet the commercial possibilities of the invention in the metal tend to blind the industrial worker to this fundamental fact and to make him hope that he can hold back the stream of progress at the precise stage where he had made his own contributions. The patent system and the commercial value of an investor's idea as something salable tend to push him in this direction." [2]

Several types of such complexes are classified in the USA by the way the basic elements of a scientific and technical centre are grouped. There are full complexes, consisting of three main elements: new science-intensive industries, universities and government laboratories. The most famous of these is the Cambridge Research Laboratories on Route 128, in the Boston area.

Complex-type scientific and technical centres are pivotal not only to scientific but also to socio-political life, and their activity frequently acquires global scope. Every possible aspect of various areas of the globe are being studied by scientific complexes in the USA which are

[1] *Harvard Business Review*, January-February 1965, pp. 141-42.
[2] Norbert Wiener, *I Am a Mathematician*, New York, 1956, p. 267.

financed by the state and private benevolent funds. A special stratum of scientific consultants and science politicians is taking shape. One of those who came from Cambridge was Professor Henry Kissinger. Such centres elaborate programmes for modernising the methods used by the foreign policy apparatus according to the last word in cybernetic techniques. It is not surprising, therefore, that a high value is put on the proximity and accessibility of Cambridge's intellectual potential, which is much more important than the proximity of sources of raw materials or suppliers of semi-finished products and components. The importance of this proximity in science and capital- but not material-intensive and technically intensive electronic production based on it tends to recede.

Another type of US scientific centre consists of two-element research complexes based only on solid universities and scientific and technical firms. Examples are offered by Palo Alto (California) and Ann Arbor (Michigan), which rival Cambridge in many respects. In the former, Stanford University has a cluster round it of more than 40 firms. The latter has brought together in the process of its formation about 24 firms with scientific and technical businesses resting on Michigan University.

Washington, D. C., is an example of the third type of research complex, which has two elements: government centres and allied scientific and technical firms. Nearly one hundred such firms will be found in the Washington area, many of them founded by former government officials.

Finally, the fourth type of complex is confined mainly to scientific and technical firms and their laboratories, and specimens of these will be found in San Diego (California) and in Orlando (Florida), where leading aerospace corporations with a great number of small technical subcontractors are based.

The trend towards the formation of complete or incomplete "scientific complexes" in applied R & D bears directly on the solution of the problem of ploughing new scientific and technical achievements into production and effecting scientific and technical innovations.

In modern scientific and production complexes, the technology transfer problem is frequently solved through the smooth spread of new ideas among the laboratories,

departments and subsidiaries. This helps to accelerate the realisation of scientific and technical innovations.

The formation of research parks has engendered new forms of private enterprise like companies for the production of companies. Thus, the American Research and Development Corporation was organised on June 6, 1946, as a commercial enterprise registered as a regulated closed undiversified company for investment management. It has common interests with other investor companies, including the Canadian Enterprise Development Corporation, Ltd., set up in 1962, and the European Enterprise Development Company, established in 1963. The former had a 9 per cent and the latter a 7 per cent interest in ARDC. Its main function is to research into new and existing enterprises, processes or lines of products from the standpoint of their commercial potential and also to make available capital and management expertise to enterprises or organisations emerging on that basis. The ARDC does not directly interfere in the production and marketing of the new lines of products or in extending loans to third parties. But it has unlimited powers to invest its assets in stocks, bonds, etc. In some instances, it may establish control over other companies.

By the earl y1960s, close to 30 such companies had been set up with the aid of the ARDC, and its holdings were estimated at $29 million in 44 companies, including one in Canada and another in Europe. [1] But most of them are part of the Cambridge scientific complex. In early 1969, the ARDC had 7,605 stockholders, and a net income of more than $813,000. It had strong formal and informal ties with various leading representatives of the business and scientific world. [2]

Within the framework of diversified concerns, vertical technology transfer largely coincides with horizontal transfer. However, there are more difficulties in transferring new ideas between individual firms because of capitalist competition which requires secrecy, and so on.

The possibility of overcoming these obstacles depends directly on the ratio between the necessary initial outlays and the commercial returns (fall-out), which depend on

[1] *U.S. News & World Report,* September 21, 1964, p. 56; *Harvard Business Review,* January-February 1965, p. 141.

[2] See, *Moody's Bank & Finance Manual,* April 1969, p. 905.

the innovations, and this ratio, for its part, depends on the size of the firm. E. Mansfield showed in his early 1960s studies that while new hardware and technology generally tended to diffuse slowly and unevenly in industries like coal, steel, beer-brewing and railways, the speed of diffusion was a direct function of the profitability of a new idea and a falling function of the magnitude of the required inputs. A study carried out by Mansfield under a contract from the US National Science Foundation showed that the size of the firm and the profitability of the innovation were important factors which determined the speed with which one firm adopted it as compared with another. Fairly large firms are unstinting in supporting sufficiently profitable innovations.

The great secrecy which firms have to maintain to meet the tide of industrial espionage exists side by side with the formation of scientific and technical pools, just as competition itself exists in a contradictory unity with the tendency to monopoly which it spawns. Characteristically, parallel with the pools in the US aerospace industry, a Society for Industrial Security was set up, and its meetings were attended by more than 2,500 representatives of corporations from dozens of American cities.

The management of industrial research nowadays reveals a definite tendency to rehearse the past. The growing autonomy of the divisions of industrial conglomerates springs from the growing difficulties of exercising management from one centre as business acquires ever greater geographical and commercial proportions. The tendency towards the growing autonomy of company laboratories was only a derivative of this general tendency. This decentralisation was of much positive significance, for it released the initiative of managers and made them more independent, but there again the minuses turned out to be an extension of the pluses. Central management came to realise that with such an approach it was gradually losing its grip on the activity of the corporation as a whole, including research activity.

Consequently, there was a growing objective need for some recentralisation which could be effected through the use of control and information electronic computers. These are used to model and decide on the line of corporate activity, and their mutual complementarity was effective-

ly realised within the framework of electronic computing systems, whose original model, Marc-III, was set up by General Electric in early 1970.

The centralisation and concentration of capital (and not only in monetary form but also in the form of patents, licences and other forms of stored scientific and technical information) is a premise for the concentration of scientific production itself. At the highest hierarchical level, it is the capitalist state that expresses the tendency towards centralisation and concentration.

On the other hand, the petty-commodity production of knowledge continues to be a permanent basis and nutrient soil for monopolised scientific production. The "industry of discovery" in the broad sense of the term represented mainly by a handful of leading corporations monopolising industrial R & D rests on the "industry of discovery" in the narrow sense of the term which is represented by a mass of small and medium commercial laboratories, engineering consultants and similar scientific and technical firms. Within the "industry of discovery", the monopolies do not eliminate competition either, but coexist with it in a contradictory unity. Those which go to the wall in the monopoly competition are gobbled up by their more successful rivals, and their place is taken by new firms achieving success in applying R & D innovation. Not only the medium but also the small enterprises, while being ruined and wound up in the competitive fight and taken over by bigger and more viable corporations, re-emerge when the outlook improves and are filled out with new commercial and R & D laboratories. Big R & D business simply cannot exist without a host of subcontractors.

Consequently, monopoly and competition, concentration and decentralisation in financing R & D tend to coexist, while being expressed in different forms, depending on the concrete conditions. There is a similarly contradictory coexistence in the scientific and production sphere of the tendencies to étatisation and reprivatisation, which, in effect, feed upon each other.

On the whole, however, there is a gradual shift towards étalisation, reflecting the overall trend in the contemporary historical process, a trend towards the growing socialisation of the mechanism of social reproduction.

The contradictory trends in the shaping of the scientific network in the USA are reflected in the combination of private and public scientific centres and establishments, although the line between the two turns out to be highly tenuous. Private industrial research and industrial parks tend to emerge exclusively on a soil which is well fertilised by government contracts for the design and development of new technology. For its part, the state does its utmost to encourage private enterprise in R & D, by setting up hybrid forms of semi-governmental organisations.

A prominent recent form of the latter is the Federally Funded Research and Development Centres (FFRDC), which are set up on the taxpayers' money but work exclusively under contract from federal agencies. They are administered both by government and private universities and industrial corporations, usually on a non-profit basis. They are classed as non-profit organisations and have first-rate research personnel (with higher salaries than those in other research outfits), excellent laboratories and equipment. The research centres' budget, which has been growing from year to year, in 1975 came to 8.9 per cent of federal commitments in financing R & D, so that they have an important role to play in developing scientific activity in the United States. [1] Federally financed contract-research centres constitute an ever more important "belt gear" running from the government agencies to the scientific resources of the universities and the industrial corporations for accelerated fulfilment of the most urgent programmes.

USSR's Science Network

In the Soviet Union, the network of science centres and establishments has not taken shape spontaneously, not as a result of the interplay of private enterprise, but as a result of deliberate policy expressed in a succession of government measures for the most balanced development and location of the productive forces across the country. The principles of this policy were spelled out

[1] *Federal Funds for Research, Development, and Other Scientific Activities. Fiscal Years 1973, 1974 and 1975*, NSF 74-320, Vol. XXIII, p. 13.

by Lenin back in 1918 in his famous "Draft Plan of Scientific and Technical Work".

He proposed that the Academy of Sciences, which had started upon a systematic study of the country's productive forces, should be instructed without delay by the Supreme Economic Council (SEC) to make a study above all of "the rational *distribution* of industry in Russia from the standpoint of proximity to raw materials and the lowest consumption of labour-power in the transition from the processing of the raw materials to all subsequent stages in the processing of semi-manufactured goods, up to and including the output of the finished product". [1] We find Lenin assigning to science the key role in the study and mastery of the resources and in developing industry on the most economical basis. The Academy of Sciences did much to draw up the GOELRO, the State Plan for the Electrification of Russia, discover apatite deposits on the Kola Peninsula, major oil deposits in the Tatar Republic, and so on.

The fledgeling Soviet state sought to secure the scientific elaboration of the key economic problems, to organise the development of the most promising lines of research, and to arrange for R & D and the training of highly skilled specialists.

With the participation of leading scientists it first set up a system of agencies to direct science. These agencies, developing the existing network of academic institutes and institutions of higher learning, laid emphasis on the establishment of a new network of sectoral problem-type institutes. [2] There had been no such institutes in Russia before the revolution. Thus, in the USSR applied research was substantially "spun-off" from basic research, thereby bridging the great gap between science and practice which had been characteristic of prerevolutionary Russia.

But because the "matrix" for the whole formation of the Soviet scientific network was provided by the Academy of Sciences, it left an imprint on the organisation of

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[1] V. I. Lenin, "Draft Plan of Scientific and Technical Work", *Collected Works*, Vol. 27, p. 320.

[2] Y. A. Belyaev, "On the Spatial Aspects of the Development of Science". In: *Proceedings of the XIII International Congress of the History of Science*, Section II, Moscow, 1974 (in Russian).

science in the Soviet Union as a whole, and was especially instrumental in developing fundamental science.

In a sense, one could say that the whole of Soviet science is organised on the academic system. [1] The USSR Academy of Sciences, the basis of this system, combines the functions of the chief source of basic research and the country's chief scientific centre, and also—alongside the State Committee of the USSR Council of Ministers for Science and Technology and the USSR State Planning Committee—of one of the chief scientific and political agencies of the Soviet state. The CPSU Central Committee's Report to the 25th Congress of the CPSU said: "It is the Party's policy to continue showing tireless concern for the promotion of Science and for its headquarters, the Academy of Sciences.... In it is concentrated the flower of our science—venerable scholars, founders of scientific schools and trends and the most talented young scientists blazing new trails to the pinnacles of knowledge. The Party highly values the work of the Academy and will enhance its role as the centre of theoretical research and the coordinator of all scientific work in the country." [2]

It can hardly be accidental that the structure-forming element of present-day scientific centres is provided by the institutions of the Academy of Sciences specialising in basic research, for their role goes well beyond the framework of the Academy itself. In this respect, we have gained unique experience which has its origins in the establishment of a network of branches of the USSR Academy of Sciences in remote areas of the Russian Federation and the Union republics as the basis for the subsequent establishment of republican academies of sciences.

Only four per cent of the country's scientific workers are employed by the Academy of Sciences. [3] Together with the higher schools, academic scientific establishments make up less than one-third of the total of scien-

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[1] See, M. S. Bastrakova, *The Formation of the Soviet System of Science Organisation*, Moscow, 1973 (in Russian).

[2] *Documents and Resolutions. XXVth Congress of the CPSU*, pp. 57-58.

[3] *Public Education, Science and Culture in the USSR*, Statistical Collection, Moscow, 1971, pp. 245-46 (in Russian).

tific establishments in the USSR, but they are the ones that lay the scientific groundwork for the long-term development of science, technology and production. *Complex and specialised scientific centres* of academic origin have the task of translating this reserve into R & D innovations as soon as possible.

A major and complex science centre, based on the Siberian Branch of the USSR Academy of Sciences, organically combines basic research in a broad spectrum of disciplines, ranging from nuclear physics and molecular biology to the sciences of the Earth, hydrodynamics, history and economics, with accelerated vertical technology transfer and engineering of completed research projects.

There, under the sponsorship of the Siberian Branch, academic research institutes, Novosibirsk State University and the system of applied research institutes, design offices and experimental production lines have been brought into a complex. Just now, a similar complex is being built up near Novosibirsk round the scientific institutions of the branch of the Agricultural Academy. A dozen or so research institutes and design offices of dual subordination have been set up near Akademgorodok in the vicinity of Novosibirsk. They operate under the guidance of scientists of the USSR Academy of Sciences, while being subordinate to the sectoral ministries and fulfilling contracts from industry. This makes it possible to develop scientific ideas and apply them to production. Thus, a Design and Technology Bureau, set up under the Siberian Branch's Institute of Catalysis, has been successfully elaborating the technology for the mass production of catalysts on the basis of mathematical models of chemical processes structured by academic chemists together with mathematicians. The establishments of a Catalysis Design Office by the USSR Ministry of the Chemical Industry with ample experimental facilities helps to reduce the time it takes to realise the projects of the Siberian Branch's Institute of Catalysis from 10-12 to 3-4 years. [1]

Some 10 years ago, scientists of the Siberian Branch proposed 10-15 concrete projects for application a year, whereas today the number has gone up to 110-150.

[1] *Sotsialisticheskaya Industria,* August 11, 1971.

Under the scientific guidance of the Siberian Branch, 11 ministries and departments are now working to set up a network of applied research institutes, design offices and experimental production lines to ensure a continuous flow of discoveries and inventions from origination to engineering. [1]

A complex science centre has been set up near Sverdlovsk in the Urals. It includes 11 institutes of the Academy of Sciences in the various natural science, mathematical and social disciplines. Most of the young personnel at the centre are graduates of Sverdlovsk State University, with which the science centre has, however, no administrative links.

A major and diversified science centre has been set up in the Soviet Far East. The Council for the Productive Forces under the USSR State Planning Committee supports the idea of establishing such complex science centres in other parts of the country as well.

Specialised science centres are also being developed alongside the complex centres in the European part of the country. An example is the Science Centre for Biological Research of the USSR Academy of Sciences at Pushchino on the Oka River, which concentrates on research and development of the physico-chemical principles of vital processes.

Research at this Biological Centre is interdisciplinary. The decision of the Presidium of the USSR Academy of Sciences establishing the Centre envisaged that its institutes should make the utmost use of the ideas and methods of physics, chemistry, mathematics and some other departments of the technical sciences for the swiftest solution of the urgent problems in biology. It was also envisaged that research should be based on modern experimental techniques and that the Centre should organise the development and engineering of unique and

[1] At the Hydroimpulse Technology Design Office of the Siberian Branch's Institute of Hydrodynamics, a new and exceptionally promising technical innovation has been developed under the guidance of Corresponding Member of the USSR Academy of Sciences B. V. Voitsekhovsky. It is the hydrohammer which makes it possible to reduce to a quarter the number of operations in punching such common instruments as the wrench. An automated punching line to do this has been assembled at the Novosibirsk Tool-Making Works.

original instruments, automatons and complexes of these, and also the machine processing of experimental data.

The Biological Centre amalgamates several institutes, which were organised in different ways (for instance, the Institute of Biophysics emerged on the basis of a research establishment in Moscow which was transferred to Pushchino, while the Institute of Photosynthesis was set up at the Biocentre).[1] An analytical comparison of the various ways of organising research institutions suggests conclusions about their pluses and minuses and indicates the optimal ways of training, selection and appointment of scientific personnel.[2]

The experience gained at Pushchino helps to clarify a number of urgent matters bearing on the connection between university education and science, and the most effective forms for training young scientists and structuring new creative collectives.

Specialised science and technical centres are being set up in the Ukraine, near Kiev (Institutes of Geophysics, Geochemistry, Mineral Physics, General and Inorganic Chemistry, Metallophysics, Foundry Problems and Material Science Problems) and in Donetsk (the Donets Basin). Studies at the Donetsk Physico-Technical Institute of the use of high pressures in the technology of metal and alloy treatment to improve their physico-mechanical and working properties have helped directly to solve a number of important problems in reducing metal-inten-

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[1] Among the important results obtained at the Institute of Biological Physics is the study of the mechanism of muscular contraction, the discovery of the connection between the behaviour of the membranes of the giant nervous cell and its metabolic and structural processes, and diverse radiobiological studies. The mechanism by means of which ribosomes effect their self-assembly has been studied in detail at the Institute of Proteins. The Institute of Photosynthesis has shown the dependence of the make-up of the electron carriers in the photosynthesis electron-transport chain on the conditions of plant growth, and so on.

[2] The specific feature of the Pushchino Biological Centre is that it is a relatively closed system, and this makes for a special style of the scientists' work, everyday life and contacts. But the Biological Centre is connected with Moscow State University and a number of other institutions of higher learning, whose students receive their practical training at its institutes and also provide the bulk of the new scientific personnel.

sivness and enhancing metal quality. This is evidence of both vertical and horizontal technology transfer, from enterprise to enterprise, from industry to industry, and from region to region. A new science centre is being set up near Leningrad on the basis of the successful experience gained by the complex centre at Akademgorodok near Novosibirsk, and also by the specialised science centres near Moscow (Pushchino, Chernogolovka, Krasnaya Pakhra, and others), near Kiev and in Donetsk. It will study not only general scientific and technical problems, but also specific regional problems connected with the development of the productive forces of the North-West.

The construction of science centres is being carried on by large state organisations like the Ministry of Assembly and Specialised Building Work, the Ministry of Industrial Building of the USSR, and Akademstroi.

The complete plant for existing and remodelled science institutions is an important form of material and technical back-up for scientific and technical progress. With the growing scale of research and the formation of regional science centres the need for investments into the development of regional productive forces and for objective-geared scientific programmes at the Novosibirsk and Krasnoyarsk centres, at Obninsk and other science cities has grown considerably. [1]

Of the new science centres being set up in the Urals, the Soviet Far East and the North Caucasus, the latter has its own structural peculiarities.

Up to now, institutions of the USSR Academy of Sciences and its branches, and later of the republican and partly of the sectoral academies (like the All-Union Academy of Agricultural Sciences) have mainly provided the structure-forming element in the establishment of Soviet science centres. But as the network of academic institutes developed, they tended to draw off a growing body of the highest-skill research personnel from other scientific institutions, the institutions of higher learning, in the first place. Of course, the separation of

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[1] "Economic Aspects of Scientific and Technical Progress". In: *Proceedings of an Interrepublican Scientific Conference on the Economic Questions in Scientific and Technical Progress*, Section I, p. 154.

the function of teaching from the function of research has never been absolute. Lecturers at Soviet higher schools spend roughly one-half of their working time on research. On the other hand, scientists at the Academy of Sciences do much to train postgraduates, lecture, give consultations, arrange seminars, and so on. But the organic fusion of research and teaching, as required by the current scientific and technical revolution, has not been quite adequate in scale. The problem of raising the degree to which the scientific potential of the higher schools is used (while raising the level of training of specialist personnel) is being tackled by the higher school complex science centres now being set up in various parts of the Soviet Union.

One of the first of these is the North Caucasus Centre, which covers a whole region with such major cities as Rostov-on-Don, Taganrog and Novocherkassk.

This Centre is based on a higher school, namely, Rostov-on-Don State University, which has brought together the 43 higher schools and the more than 20 research institutes in various fields located in the region. Among them is the All-Union Institute of Vine-Growing and Wine-Making and the Taganrog Radio Engineering Institute, the Novocherkassk Polytechnical Institute and the Institute of Neurocybernetics. Some institutes of the Centre have powerful design offices and are closely linked with production both in their region and in the country as a whole.

This type of science centre, which is common in the United States and other Western countries, has also very good prospects in the Soviet Union. A Republican Scientific Experimental Association of the Ministry of Higher and Specialised Secondary Education has been set up in the Russian Federation. It is based on the higher school with its research subdivisions and experimental production shops. Zonal interhigher school scientific experimental centres bringing together research institutes and design offices into an academic, scientific and production complex are being set up in every region and town. This helps to make much more efficient use of the research potential of the higher schools, which in the USSR have something like 2,600 research establishments and almost one-half of the scientific personnel, to say nothing of the

57,000 postgraduates and 4.6 million students.[1] Establishments of the Soviet Far East Centre are being set up together with the subdivisions of Vladivostok University and the Polytechnical Institute. Higher schools are an important element of the new science centres at Tyumen, Tomsk, Sverdlovsk, Kuibyshev and Tbilisi.

The complex and specialised science centres show very well that within the matrix of scientific and technical progress horizontal and vertical links are interrelated. The closer the contacts between the sciences, the more successful the application of their integral achievements for the solution of complex problems at the technico-technological stage. Valuable experience in this area has been gained at the academies of sciences of the Union republics. At the Academy of Sciences of the Latvian Republic, for instance, contractual R & D projects make up 15 per cent of the total outlays, and in the academies of sciences of the Ukraine and Byelorussia, almost 30 per cent.[1] Thus, Ukrainian mathematicians, who have a leading place in research into the theory of nonlinear differential equations and the theory of the nonlinear vibration, have been successfully working on methods to solve problems in applied mathematics by means of electric modelling. Electronic computer modelling of some physical, chemical and biological processes helps markedly to speed the development of this field of knowledge. At the same time, the development of the fourth and subsequent generations of electronic computers is of tremendous importance both for science and practice.

Studies of food and raw material resources in the World Ocean carried out jointly by oceanologists, geologists and geophysicists of the Ukrainian Academy of Sciences have been increasingly complex in character both along the horizontal and along the vertical. While enriching each other, the sciences of the Earth help society to increase its material wealth: the proved oil deposits on the seabed have increased by 50-100 per cent the oil deposits explored on the land. In the second half

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[1] *The Economy of the USSR. 1922-1972,* pp. 103, 107, 430 (in Russian).

[2] *Proceedings of an Interrepublican Scientific Conference on the Economic Questions in Scientific and Technical Progress,* Section I, p. 130.

of the 1960s, the institutes of the Georgian Academy of Sciences carried out 250 applied research projects, 21 of the most important ones having been realised in practice in Georgia and elsewhere.

The shaping of the science centre network in accordance with the academic "matrix" (Academy of Sciences—higher schools) is due to the fact that scientists involved in basic research are endowed with a kind of "instinct" for self-organisation. The tendency towards self-organisation, which is deeply latent in the very fabric of basic research, goes beyond the framework of this type of scientific activity, increasingly permeating applied research and the production of scientific knowledge as a whole. This is promoted by the leading role of basic research in scientific activity, a role it has to play above all in information, by supplying an uninterrupted flow of scientific information about the fundamental principles of the universe. From this it logically follows that basic research also has the leading role to play in the organisation and administration of science. Science-technology complexes and specialised centres (alongside these, some students of science also bring out science-production centres) have a two-fold task to fulfil. On the one hand, they ensure a more even location of science across the country and, consequently, more intensive development of its productive forces. On the other, such complex and specialised centres as those at Obninsk, Zhukovsky, Zelenograd near Moscow and Salaspils near Riga provide a framework for the uninterrupted transfer of fundamental knowledge to production through intermediate applied elements. What is equally important is that simultaneously there is a conjunction of research, instruction and education. In this way, the science centre network helps to tackle the problem of "technology transfer" both along the vertical and along the horizontal.

Industrial Centres of Innovation

The task of converting new ideas into scientific and technical novelties has to be tackled by the extensive network of sectoral and other applied research institutes and design offices, industrial laboratories, scientific design subdivisions, large enterprises (Uralmash Works, and

Gorky, Volzhsky and Kama Motor Works), combines and science-production and production associations. Before the socialist revolution, the country had nothing like it, and the establishment of this network should be regarded as a key act of purposeful planned development of the modern structure of scientific activity in the Soviet Union.

Alongside the academic system of organisation of basic research, the applied research institute network has also been broadly developed in the USSR. The two are closely tied in with each other. The establishment and consolidation of the fundamental basis of Soviet science insistently demanded a complement in the form of an adequate basis of applied research, as a necessary element in the organisation of R & D innovations in various sectors of the economy. In the 1940s and 1950s, the establishment of the network of republican and sectoral academies was in the main completed, and in the 1960s a network of sectoral applied research institutions was developed on a broad scale, which employed almost one-half of the scientific personnel of the USSR.

Sectoral R & D institutions were subordinated to departments and economic councils, which, however, frequently tended to proliferate the number of such institutes not only for scientific but also for prestige and similar considerations, without displaying due concern for their high-quality composition and productivity or their actual capability of tackling the truly pressing problems in the relevant sectors. As a result, while being far-flung, this network of applied research institutes was unable to provide a reliable bridge from theoretical science to production practice, and the highly productive institute here and there could do nothing to change the overall picture. That is why to fill the gap there arose the need to set up a highly efficient system for development and engineering of the latest scientific and technical achievements.

The 1970s marked a new stage in the balanced shaping of the Soviet science organisation system. The most important thing here was the final stage of scientific and technical innovation, the stage of development and engineering.

As I have already said, at the development and engineering stage, costs tend to be a whole order higher.

That is why organisational measures will yield real results only if they rely on economic instruments. Decree No. 139 issued by the CPSU Central Committee and the USSR Council of Ministers on March 2, 1973, said that the country must have a single set of methods for determining economic efficiency providing for the possibility of correcting the plan targets of the enterprises. It said that the establishment of centralised funds for developing new technology by sector should go hand in hand with a restructuring of the science network organisation. Take the experience gained in the electrotechnical and later in several other industries where the size of such funds is strictly geared to the profits earned by the ministry. Parallel with the establishment of centralised funds, which cover more than one-third of the budget of sectoral research institutes, their affiliates and smaller institutes located across the whole country were directly subordinated to the enterprises concerned. For their part, the sectoral research institutes were given control of nearby plants, which came to be their production basis. This helped substantially to eliminate the artificial barrier between the institutes and the plants and to accelerate scientific and technical progress. The research institutes in the electrotechnical, oil and certain other industries were joined together with the corresponding design, development and technological organisations and experimental plants as component parts of *complex institutes*. More than 20 such institutes in the electrotechnical industry have been provided with funds and authorised to finance R & D and to control fulfilment of projects. They exercise scientific and technical guidance along the leading lines, plan for new hardware and technology, and help to link up all the phases of the "research-development-engineering-manufacture of new products" cycle. This is achieved through the issue of standard order-warrants designating all the developers and performers of the topic and the makers of the new product, and giving an evaluation of the costs at the various phases and as a whole. These complex institutes are highly flexible, and are capable of restructuring their organisational ties, setting up integrated teams of scientists, engineers and technicians to tackle concrete scientific and technical problems and to realise objective-geared programmes. This helps

to halve and further to decrease the time it takes to develop and introduce into production new machinery, equipment and technological processes.[1] In two and a half years of work under the new system, the All-Union Institute for Research into Electrothermic Equipment reduced the time it takes to introduce finished projects by an average of four months, and the overall construction cycle, by 27 per cent. From 1968 to 1971, the share of research and fundamental work increased from 10 per cent to 19 per cent, and of multifield topics of importance for the whole ministry from 7.7 per cent to 17 per cent. Equally high results have been achieved in machine-tool building by the ENIMS complex institute in Moscow, which constitutes a single whole with the Stankokonstruktsia Experimental Works.

Ever more attention is now being given to accelerating scientific and technical innovations. A system of economic, legal and organisational measures has been mapped out to tackle this task. The important thing here is that the basic organisational form which helps to put through the system of planned measures has sprung from actual needs. This form is known as the *production and science-production associations.*

To accelerate scientific and technical progress, L. I. Brezhnev emphasised, it is important to improve the forms of organising industry, securing, so to speak, the kind of production pattern that would be abreast of the demands of the time. This implies a considerable extension of research and development in industry itself, the establishment at the enterprises of design bureaus, of a resourceful experimental base, and an influx into industry of a large number of researchers. Naturally, only big amalgamations and combines can accomplish this, which makes their establishment particularly topical. In many cases, good results may be obtained by merging research institutions with enterprises, and creating powerful science-production complexes.[2]

In accordance with this, the General Statute on All-

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[1] *Proceedings of an Interrepublican Scientific Conference on the Economic Questions in Scientific and Technical Progress,* Section I, pp. 28-29.

[2] See, *Documents and Resolutions. XXVth Congress of the CPSU,* p. 57.

Union and Republican Industrial Associations provides for the following rights and duties of associations in the field of scientific and technical progress:

the association shall work out scientific and technical prognostications on the key problems in the development of the sector (subsector) or participate in their elaboration, making use of the technico-economic indicators of these projections for research, development, engineering and technological work, and work in standardisation and unification;

in accordance with the established management procedures, the association shall work out and approve long-range and annual plans for research and the use of scientific and technical achievements within the framework of the association as a whole;

for the purpose of raising to the utmost the technical level of production and of the standards of the products turned out, the association shall carry out on its own and in cooperation with other associations and organisations, research, development and technological projects, work in engineering and manufacturing new lines of products, materials, means of mechanisation and automation, work to improve hardware and production techniques, organise labour on scientific lines and effect the complex fulfilment of the whole cycle of scientific and technical tasks;

the association's board shall put through measures to enhance the efficiency of R & D, and take steps to create the necessary experimental production facilities and also to carry on scientific and technical cooperation with foreign countries in accordance with the approved plans. [1]

Science-production complexes are the most progressive form for combining science and production, which has been engendered by life itself. Such complexes (*associations*) may consist of research, design, development and other organisations together with experimental, industrial or agricultural production. [2]

The amalgamation of research institutes and plants within the framework of one organisation—the science-

[1] *Proceedings of an Interrepublican Scientific Conference on the Economic Questions in Scientific and Technical Progress,* Section I, pp. 270, 271.

[2] Ibid., p. 29.

production associations—helps to tackle a most difficult problem, namely, that of overcoming the barrier between diverse enterprises and departments. The associations have the task of saving time on coordination in the transfer of technico-economic documents from one organisation to another: from research institutes and design offices to experimental plants, and from there to industry for batch production. [1] Within the science-production associations, production is concentrated on the basis of thoroughly considered specialisation. Associations are usually headed by the director of the research institute, and it is the institute and not the plant that has the crucial role to play in deciding on technical policy and the strategy of the association.

Science-production associations are a form of production association where the research, design or development organisation has the leading function. This form of merger within a single complex of research establishments and enterprises gives scientific and technical ideas a short cut into production, and helps to concentrate production and centralise material and financial resources on an advanced scientific-organisational basis. The Soviet Union's first science-production associations emerged in the science-intensive industries—radio-electronics and chemicals—in Lvov and Leningrad in the 1960s.

Their main task is to secure a complex solution of scientific and technical problems from the stage of research to the engineering of new hardware (technology) and their batch production.

Science-production associations are responsible for the scientific and technical level of production and the products turned out in the whole industry, and coordinate research, development and technological works, in accordance with the specialisation laid down for the organisations, associations and enterprises in the industry. Science-production associations have the task to secure balanced development of science and technology, to synchronise the steady flow of all the stages in the development, manufacture and introduction of new hardware,

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[1] *Proceedings of an Interrepublican Scientific Conference on the Economic Questions in Scientific and Technical Progress*, p. 28.

eliminating any organisational discrepancies between the individual stages of this process.

At the beginning of 1976, the Soviet Union had over 2,300 production and science-production associations. In Leningrad alone, they numbered several dozens. Rapid advance of this form of merging science and production was held back by the difficulties which tend to arise in any new undertaking. The approval of a standard statute for science-production associations enabled the planning and economic agencies to take due account of the specific features of this form and to apply an independent system of indicators for them. [1]

Batch production cannot but hold back experiments with technical innovations (and this is also true even for such a large production association as the Leningrad Elektrosila Works). In view of the specific features of the science-production associations, a number of ministries have decided sharply to cut back the volume of mass production, switching the science-production associations to experimental small-batch production.

With the switch to the two- and three-tier system of management of social production, the science-production associations should become one of the basic economic-calculus elements in production, which is being transformed on scientific lines.

The establishment of science-production associations enables the ministries to concentrate planning and applied research, development and experimental work and to accelerate the use of their results in the economy despite the remaining departmental barriers and narrow-minded local approaches. General schemes of long-term plans for improving industrial management assign an important place to the science-production associations in accelerating the pace of scientific and technical progress and in making it more efficient. Science-production associations enlarge the horizons for sectoral scientific and technical policy by releasing it from the need to tackle day-to-day tasks and making it possible to concentrate on the strategic tasks of long-term prognostication and planning.

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[1] Ibid., pp. 30, 31.

The science-production associations provide a concrete organisational form for realising the potentialities of the scientific and technical revolution under the socialist economic system. hTe existence within scien-production associations, like Plastpolimer, of research, development and experimental units gives the green light to the continuous movement of a technical conveyer belt—"research-development-production"—helping to halve the time it takes to realise ideas while doubling the benefits. The council set up under the director-general of the science-production association works to centralise the activity of the functional services and departments on a matrix basis. Prognostication and comprehensive stage-by-stage planning of R & D is carried out, parallel and joint research, design, experimental and tooling-up and starting operations are organised under systematic supervision. A large number of administrative and management personnel (60-70 per cent) is released for other jobs, and the conditions for putting through plans for the collectives' social development are improved.

The earliest reports on the science-production associations' activity brought out their advantages. The duration of the "science-production" cycle was reduced, for instance, at the science-production association in Leningrad by 50 or even 75 per cent as compared with the showing by enterprises not included in the association. Labour productivity was markedly increased, and fluctuation of personnel reduced. Science-production and production associations have a great future ahead of them in this age of the scientific and technical revolution. What is especially important for the long term is that they open up the broadest potentialities for making efficient use of the latest automated control systems (ACS). The experience gained by Soviet science-production associations has confirmed that they yield a real effect, provided their organisational structure is sufficiently clear-cut, that the channels of communication are smooth, and that the barriers to the flow of information are removed.

In the USSR, dozens of specialised *organisations (associations) for the introduction of new hardware and technology* have also been set up. These have technological-design, experimental-engineering, and tooling-up and assembly units, completing and introduction services, and

their own scientific and technical experts and consultants. Their main task is to help enterprises and associations to introduce scientific and technical achievements into mass production and to transfer advanced experience. They are set up within all-Union and republican industrial associations, ministries and departments to effect the setting up and finishing of new hardware and technology, master new production techniques, carry out tooling-up and starting operations, act as sponsors of assembly operations when new hardware and technology are introduced and to provide the required complete sets of technological rigging. The organisations (associations) for the introduction of new hardware and technology ever more frequently act as middlemen between research and production organisations.

Scientific and technical progress is promoted by the inclusion of technological services of enterprises and associations within design offices and research subdivisions. Thus, a powerful science-technology centre has been set up at the Uralelektrotyazhmash Production Association. At the large Azovkabel Association, an integrated New Hardware and Technology Service has been set up to carry out the whole range of operations from the preparation of the technical assignment to the introduction of the new lines of products and production techniques in industry. It includes technological design subdivisions, a technico-economic grounding office, a completing office, and a department for the introduction of new hardware and technology with an experimental section. [1]

Network Dynamism and Personnel Mobility

The growing dynamism of scientific organisation makes ever greater demands on every type of mobility of scientific and technical personnel.

The main instrument for regulating the proportions in the structure of scientific personnel as the "leaders" in scientific, technical and socio-economic progress change

[1] *Proceedings of an Interrepublican Scientific Conference on the Economic Questions in Scientific and Technical Progress,* Section I, pp. 31-33.

places is naturally provided by the system of their training through the higher schools and postgraduate studies. But the operation of this instrument is being delayed for the period of years it will take to carry out the time-consuming remodelling of the education system. But time is pressing, and here the mobility of scientific personnel comes to the rescue: physicists, chemists and mathematicians have been moving into biology, and together with biologists into sociology and the science of science, into psychology and medicine. Thus, in the United States large groups of trained chemists (86,980 in 1970) work, apart from chemistry (53,641), biochemistry (3,167), and physical chemistry (4,597), in food science (567), mathematics (242), biology (2,087), physics (346), economics (1,022) and other fields of knowledge. We find the same picture in physics, biology, mathematics, statistics and other fields. In psychology we find, alongside trained psychologists, statisticians, biologists, mathematicians, sociologists, linguists, physicists, economists, chemists, meteorologists, and so on. [1]

But social conditions tend to leave an imprint on the movement of scientific personnel between fields and organisations.

Frederick H. Harbison says that "in planning for the development of scientific manpower, the United States must deal with two critical problems: First, it must 'accumulate' this form of human capital more rapidly than ever before. Second, it must 'invest' its stock of this capital more effectively—meaning simply that it must make better use of both the existing stock and the future supply of scientific personnel." [2]

Corporate management has come to realise that the correct policy in the selection, recruitment and maintenance of personnel is as important as the financing of sections of the research spectrum, so that without good personnel no appropriations for science will yield fruit. Besides, despite the growing cost of scientific equipment, the cost of research and ancillary labour continues to

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[1] *American Science Manpower 1970,* NSF 71-45, Washington, 1971, pp. 82-83.

[2] *Proceedings of a Conference on Academic and Industrial Basic Research,* Washington, 1960, p. 46.

account for the lion's share of the outlays on industrial research. Simon Marcson says: "The allocation of research resources is determined by the laboratory's success in manpower recruitment. The cost of research equipment and facilities for scientific manpower are an additional but secondary consideration." [1]

Entrepreneurs are inclined, when increasing under the pressure of competition their R & D outlays and allocating the bulk of these outlays on salaries for researchers, to regard the latter as a component part of variable capital, which should yield a profit. But these expectations are not always realised. In more than 50 per cent of the cases (when considering basic research programmes) they flounder in the sea of uncertainties inherent in the research itself, where it is rarely possible to attain the goals set in advance by the selected means within the expected period.

Research administrators interviewed by the National Science Foundation were unanimous in declaring: "As research overhead costs rise to $25,000 or more per man, the concern with the need for criteria for judging research productivity increases. Until such criteria are developed, the difficulties involved in convincing top management of the wisdom of research undertakings will continue." [2] The urge on the part of businessmen to derive profits from research, as from any other business, clashes with the urge to obtain scientific results, which may not have any immediate market value.

When taking a job in industry, the researcher stands to gain in terms of material conditions (higher salary, more expensive equipment, ancillary personnel, and so on), but he loses out in terms of necessary conditions for scientific creativity like academic freedom, unhampered exchanges of information with his colleagues, and free publication of research results. However, the management of various large corporations have deemed it advisable to encourage such activity in their laboratories in order to enhance business reputation, create

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[1] Simon Marcson, *The Scientist in American Industry,* New York, 1960, p. 117.

[2] *Proceedings of a Conference on Academic and Industrial Basic Research,* p. 82.

publicity for the corporation and to recruit prominent scientists.

On the whole, it is considered that industrial research laboratories offer the scientist better opportunities for research than the average college or small university. [1] Together with the ups and downs of supply and demand for research manpower this tends to increase the mobility of scientific and technical personnel in the industrial and government sphere, on the one hand, and in the academic sphere, on the other. During the "research boom" in the 1960s, US university and college graduates did not attach primary importance to starting salaries when deciding to take on jobs in industrial laboratories. Of much more importance were "personal freedom", professional advancement, the scientific environment in the laboratory and the excellent facilities. [2] However, the market regulation of supply and demand for scientific and technical personnel has revealed its limitations. The economic crisis has sharply worsened the condition of scientists and technicians, and the unemployment among those engaged in R & D in 1975 came to 4.5 per cent. The "value system" has also changed, with more importance being attached to reliability of employment and some certainty in the future.

The interpenetration of the sciences and their growing integration within the framework of joint collective programmes is being realised in the Soviet Union and other socialist countries on a different social basis. Socialist planning takes account of the objective tendency under which the integration of the sciences is reflected in the professional redistribution of the mobility of their personnel. But here the crucial point is the personnel requirements of the economy in the various scientific fields and in the priority development of the various departments of scientific knowledge. Table IV-2 shows the changes in the science-sector make-up of personnel in the USSR over 20 years.

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[1] *Proceedings of a Conference on Academic and Industrial Basic Research*, p. 43.

[2] Ibid., pp. 46-47.

Table IV-2

Scientific Personnel in the USSR in the Various Fields of Science, October 1955, end of 1965 and 1974 (1,000)

Science	Number of personnel			Of these with scientific degrees					
				doctors of science			candidates of science		
	1955	1965	1974	1955	1965	1974	1955	1965	1974
All fields	*223.9*	*664.6*	*1,169.7*	*9.5*	*14.8*	*31.7*	*77.9*	*134.4*	*309.5*
Physico-mathematical	20.1	63.9	116.9	0.8	1.6	3.8	5.4	12.2	32.7
Chemical	16.4	33.5	53.7	0.6	0.8	1.7	4.6	7.6	17.8
Biological	11.0	27.1	45.5	0.9	1.6	3.0	5.5	10.6	22.3
Geological and mineralogical	5.7	16.4	24.5	0.5	0.8	1.3	2.3	4.5	10.3
Technical	61.1	298.8	548.0	1.9	3.0	6.6	20.6	34.8	96.3
Agricultural and veterinary	15.1	30.6	36.5	0.7	1.0	1.2	6.0	9.3	15.9
Historical and philosophical	15.3	23.0	43.8	0.3	0.8	2.4	6.9	10.9	19.0
Economic	8.2	30.7	80.1	0.2	0.5	1.4	3.8	7.8	21.9
Philological	17.7	37.2	51.6	0.2	0.5	1.3	4.1	6.8	11.3
Geographical	3.4	5.9	8.3	0.1	0.2	0.4	1.3	1.9	3.2
Juridical	1.6	3.3	6.3	0.09	0.2	0.3	1.0	1.6	5.9
Pedagogical	11.5	22.5	30.2	0.07	0.1	0.5	1.9	3.1	3.1
Medical and pharmaceutical	25.3	36.7	59.0	2.8	3.2	6.6	12.4	18.2	36.4
Art criticism	4.0	8.3	14.5	0.08	0.08	0.2	0.6	0.8	1.5
Architecture	0.9	2.0	3.3	0.03	0.05	0.1	0.4	0.6	1.0
Psychology	—	—	2.8	—	—	0.1	—	—	1.2
Other fields	6.5	19.8	39.5	0.02	0.1	0.4	0.9	3.5	6.7

Source: *Public Education, Science and Culture in the USSR*, Moscow, 1971, pp. 252-53; *The Economy of the USSR in 1974*, p. 144 (both in Russian).

From 1955 to 1974, the total number of scientific workers in the USSR increased by over 5-fold, with the number of doctors of science going up 3-fold, and of candidates, nearly 4-fold. The emergence in 1970 of a new and important branch of the psychological sciences reflects the above-mentioned tendency towards the growth of the human factor within the system of social production and the need for its comprehensive study. But the traditional fields of knowledge have also developed highly unevenly. There was the fastest growth in the number of economists, almost a 10-fold increase in the 20-year period, with the number of doctors of economic science going up 7-fold and of candidates, nearly 6-fold.

We find almost the same rate of growth in the technical sciences, where the total number of scientific workers increased almost 9-fold, including doctors of technical science over 3-fold and candidates, 4.6-fold. This department has not only remained the largest in terms of numbers, but has also increased its superiority in the number of scientific personnel: in 1955 it had 3 times as many personnel in the next largest department, that of the physico-mathematical sciences, and in 1965, almost 5 times as many; by 1974, the gap had been somewhat narrowed (to about 4 times).

The faster growth in the number of economists and technicians is inseparable from the requirements arising from the use of scientific and technical progress in the economy, a process which reflects a world tendency. Thus, in the United States there is an analogous faster growth in the number of research engineers and specialists in economics and business, although their share in the total number of scientific personnel is much smaller than it is in the USSR.

The prevalence of technical personnel in the total number of scientific personnel in the USSR (and of technical institutes and other scientific establishments) is of a two-fold character. On the one hand, it tends to upset the necessary proportions in scientific activity, so that over the past few years steps have had to be taken to normalise these proportions. There is need to improve the qualification make-up of scientists in the technical sciences: the number of those with doctoral degrees, for instance, is smaller than it is in medicine and pharma-

cology, where the total number of personnel comes to only one-eighth. The technical sciences have, respectively, 4.7 and 12 times more personnel than the physico-mathematical and biological sciences, but only twice as many doctors.

On the other hand, the slight excess of scientific personnel in the technical sciences helps to accelerate scientific and technical progress in fields like energy resources, ecology, urbanisation, the transport and communications system, and so on. The body of skilled technical personnel is an ever more important component of the spiritual infrastructure of the contemporary social system.

The central task in the administration of science is the need to unfold a broad front of research and to consolidate the interaction between scientists in the natural, technical and social sciences. [1] This springs from the logic of comprehensive development which characterises present-day science. The integration of the sciences has gone hand in hand with their differentiation.

The interpenetration of scientific methods[2] has paved the way for interaction between men working in various scientific fields. This, for its part, helps them to move between organisations on the same level (say, between research institutes) and on different levels (say, between institutes and enterprises). Above I dealt with a form of mobility like *scientific business trips,* when those who travel enter into more or less close but always temporary contacts with other organisations. Rationally planned business trips may yield an immediate and considerable effect.[3] *Trainee arrangements,* which are temporary, even if longer than business trips, are also equally effective. [4]

[1] *Documents and Resolutions. XXVth Congress of the CPSU,* p. 87.

[2] See Chapter Three.

[3] Thus, enterprises in the Transcarpathian region economised 734,000 rubles by applying to production the ideas brought back by their personnel from business trips to various localities.

[4] Scientists at the Institute of the Biochemistry and Physiology of Micro-Organisms of the USSR Academy of Sciences invited personnel from shop laboratories and shift superintendents from the Akrikhin Plant for a long trainee period in order to accelerate the transfer to production of their new technological process for obtaining an important medicinal preparation. These newcomers, having received the necessary theoretical

The institution of trainee researchers has been broadly adopted in academic institutions and the higher schools. Thus, establishments of the Pushchino Biological Centre seek to use trainees to meet their basic requirements in research personnel.

The institution of trainees shows that temporary organisational mobility may become permanent. The recruitment of trainee researchers enables the organisation seeking to recruit scientists for permanent jobs to have a closer look at them in advance, and allows the prospective scientists to learn about the organisation. This helps both parties to engage in long-term businesslike cooperation. But this is a method which is not always available. The management of organisations have more frequently to decide the question of taking on "strangers" on the basis of their scientific reputation, their vital statistics, references and sometimes even of informal recommendations by various authoritative persons. In such instances, decisions are far from always correct, and the ultimate result depends on the motives for which the newcomer takes on the job.

Earlier on I considered the motivations of those engaged in scientific activity. Why are they impelled to change their jobs? The answer is obvious: the lack, above all, of due satisfaction with their old jobs. The results of our poll have brought out the absolute prevalence in the hierarchy of inducements behind scientific endeavour of the highest motivation, which is the satisfaction derived from the very process of cognition and creativity (92.77 per cent), and this was way ahead of material incentives (33.14 per cent), and broad public recognition (reputation) (15.27 per cent). This accords with the data of a 1964 sociological study carried out in Novosibirsk, which showed that "inclination for scientific work" came first as the motive for which men and women took on jobs at scientific institutions (34.5 per cent), whereas "better working conditions for scientific workers" enticed only 13.6 per cent of those polled.[1] Generally speaking,

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training at the Institute, carried out various studies on their own, and this helped sharply to reduce the period for mastering the new and complex microbiological process.

[1] P. I. Zavlin, A. I. Shcherbakov, M. A. Yudelevich, *Work in the Field of Science,* Novosibirsk, 1971, p. 294 (in Russian).

in the light of Maslow's motivation theory this may only mean that the more elementary factors of motivation have been largely eliminated here by the satisfactory conditions of life and work among scientific personnel.

Why then do those engaged in scientific activity change their jobs? Which way do the flows of scientific personnel run?

Here are two examples from practice which could help to clarify these problems.

A new machine to work frozen soil based on the principle of cutting narrow slits has been developed in the Mining Machine Department of the Tomsk Polytechnical Institute under the guidance of Professor O. A. Alimov. These machines are especially necessary in Siberia, for instance, in laying oil pipelines. The substitution of the new machine for conventional excavators is expected to help raise labour productivity 10-fold, from 10 to 100 metres of trench a day. I. G. Basov, who developed the machine together with Alimov, proposed a number of original technical ideas, for which he obtained author's certificates. He has brought together a group of scientific workers who have written 9 candidate's and 1 doctoral dissertations. Together with his group, Basov transferred to the Tomsk Engineering and Construction Institute, where he heads the Construction and Road-Building Machine Department.

Here is another example. A young engineer, I. A. Nikiforov, who graduated from the Polytechnical Institute went to work at the foundry laboratory of the Volgograd Tractor Works. Even as a student at the Institute, he had displayed various research capabilities, and so soon acquired a good business reputation at the Works. Nevertheless, he transferred to the Volgograd Engineering Technology Research Institute, where he defended a candidate's dissertation and was appointed deputy director for scientific work. Like Nikiforov, many other research engineers also went to work at the Institute. Why did they do so? The answer is that the Works had failed to provide them with the necessary conditions for research, because its laboratories were loaded with routine work in the control and analysis of its products, observance of technological standards and reduction of waste.

In both these instances, researchers moved along with their idea to a place where the conditions for elaborating it were better. But whereas in the first instance the vector of the researchers' interests coincided with that of social production (Basov and his group moved to a place where greater opportunities were available to realise his ideas), in the second instance this was not quite so. Nikiforov, like many of his colleagues, failed to find in industry adequate conditions for realising his ideas and "moved into science". Such migration of research personnel does not always help to accelerate the introduction of scientific and technical innovations.

At any rate, the gap between research and production, development and engineering is largely due to the fact that a clearly inadequate section of scientific personnel is employed directly in production. This is also true for scientific workers of the highest qualification. Meanwhile, in the United States, almost 26 per cent of personnel with doctoral degrees are employed in private industry. In the United States and other capitalist countries, researchers in industry are paid higher salaries than they are in universities and government laboratories. Until recently, the reverse was true for the USSR. A few years ago, directors of enterprises were authorised to raise the salaries of workers in research laboratories with scientific degrees, and the situation improved.

The development of the science network makes growing demands on scientific personnel of the highest qualification. Thus, until 1975, institutes of the Soviet Far East Centre required almost 1,000 scientists and specialists to fill all their posts. Consequently, the task is to improve the conditions for scientific activity throughout the country, notably in connection with evening out of housing and everyday conditions. Much is being done in this sense in accordance with the plans for developing existing and building new science cities in various parts of the country.

The effort to even out conditions in the organisation of research work in sectoral and territorial terms is designed to normalise the mobility of scientific personnel and to channel it in the required direction. Consequently, the more dynamic the organisation of scientific activity today, the more acute the need both to enhance the mo-

bility of scientific personnel and to regulate its correct movement in the desired direction. Such requirements are best met by the matrix-type organisational system, which helps to tie in "technology transfer" into a single whole—realisation of scientific and technical innovations along the vertical, from the origination of the idea to its engineering, and along the horizontal, across departmental and sectoral boundaries.

This also applies to some extent to the mobility of personnel between applied research institutes and academic institutes. It entails a substantial evening out of conditions for creative scientific endeavour at all the organisational echelons. Central industrial laboratories should make available opportunities for research comparable to those which are available at the applied research institutes, and the latter, comparable to those available at academic institutes.

Academician B. Y. Paton, Director of the Institute of Electric Welding of the USSR Academy of Sciences, explained the success of his Institute as follows: "Our scientists have always displayed an urge to draw on production for new ideas. This engineering orientation of their research has frequently helped to achieve in a very short time what it took years to achieve in other cases."

In the final quarter of the 20th century, as the scale of scientific activity grows, although this may slow down, one could expect it to become considerably more complicated. Evidently, the dominant aspect of this process until 1990 will be the need to solve this two-fold task: to reduce the distance the scientific idea has to travel from its origination to its engineering, while extending the radius of its impact. That is the way society can expect considerably to increase the returns from its growing outlays on science for the ever fuller satisfaction of the requirements of its members.

The network of science centres and institutions has a tangibly more important role to play in solving the two-fold problem of accelerating scientific and technical innovations. Within its structure, there should be prevalent development of integrated centres bringing together, under one direction, the training of research personnel

of the highest standard, their use for the generation of new ideas, and immediate realisation of the latter. That is why these should include universities with boarding schools, a complex of diverse academic institutes and laboratories and "the engineering belt" consisting of design offices and experimental production lines of dual subordination (to the ministry and to the academic leadership of the complex). Alongside such complete complexes, there should be (especially at the early stages) teaching-science, science-technology, and teaching-technology complexes. The most important thing here is that all these complexes should from the outset be established, located and linked up among themselves as elements of a single science network in the light of the scientific personnel dynamic. Let us note that the scientific principles for structuring such a network have been set out in Decree No. 139 issued by the CPSU Central Committee in 1973, which testify to the growing importance of the socialist state's scientific and technical decisions in further developing every level of organisation of scientific activity.

Chapter Five

The State and Science

The functioning of the science network is supplemented by government agencies authorised to conduct policy in the field of science.

In the United States and Western Europe—Great Britain, France, Germany, Italy, and the Scandinavian countries—the forms of organisation and direction of science have evolved spontaneously over the centuries. For all the distinctions in national conditions, their development has, on the whole, run along the classical path of spontaneous evolution, through the gradual and slow complexification of structures, formation and differentiation of individual agencies and functions, and the emergence of a "central nervous system" and a "brain". At first, there arose the simplest "cells" of scientific activity—schools and colleges, universities, scientific and "philosophical" societies, and academies, where the watershed between science and theology, and professional and amateur research was as yet highly tenuous. With the progress of science, as scientific knowledge differentiated and integrated, these forms became more complex and specialised, and revealed a growing tendency towards national consolidation and centralisation. There emerged national science associations, academies and institutes, laying claim to state recognition of their leading role.

The state, for its part, went to meet them halfway, realising above all the military and political importance of science. It assumed sponsorship of the leading science organisations, bestowing on them governmental or semi-governmental status. It also began to set up its own

science establishments, mainly for the purpose of providing expertise on scientific and technical projects and its policy decisions: government laboratories, experimental stations, bureaus of standards, and so on. At a definite stage—at the turn of the century—this evolution led to the emergence of some state agencies for the direction of science. In the first half of this century, these agencies did not constitute a single whole, and operated on their own, acting as the occasion required, and frequently at cross purposes with each other. Only towards the end of the 1950s did they merge into a *system* of government science-policy agencies, constituting the nucleus of the mechanism for the administration of science.[1] Let us note that the decisive impetus here came from the launching in the USSR of the first artificial Earth satellite, which opened mankind's space age and riveted attention all over the world to the achievements of the Soviet science organisation system.

The Origins of Soviet Science Policy

The mechanism of Soviet science policy has been shaped in a totally specific way which made it possible to compress the evolution of centuries into the space of a few decades. This was made possible because from the outset this development was not spontaneous but *conscious*. The results of the earlier development showed the meagreness of science organisation structures inherited from the past, which did not in any way meet the potentialities of the present or the needs of the future.

In prerevolutionary Russia, scientific life was extremely uneven and contradictory. There was an abundance of scientific talent, which bore out the prophetic words of Mikhail Lomonosov, when he said that the land of Russia was capable of producing men like Plato and quick-witted scientists like Newton. There was recognition all over the world of the discoveries made by outstanding scientists in Russia, including Lomonosov, Ni-

[1] *Evolution of the Forms of Science Organisation in the Developed Capitalist Countries*, Moscow, 1972 (in Russian).

kolai Lobachevsky, Ivan Sechenov, Dmitry Mendeleyev, Ivan Pavlov, Vladimir Vernadsky, Klementy Timiryazev, Konstantin Tsiolkovsky, Ivan Michurin and Pyotr Lebedev among others. A considerable contribution to the development of technology in Russia came from the inventions of Ivan Kulibin, Ivan Polzunov, the brothers Cherepanov, Alexander Mozhaisky, Nikolai Kibalchich, Alexander Popov, and many others.

The achievements of the men who were prominent in science and technology in prerevolutionary Russia were all the more remarkable because they had to work in extremely difficult conditions, and this explains the acute interest among prominent scientists in various aspects of science organisation.

Some outstanding Russian scientists and engineers put forward original ideas in the field of science organisation. Back in the 18th century, Mikhail Lomonosov urged that research should be closely tied in with scientific training, and for that purpose set up Moscow University. Mendeleyev produced a bold project for reforming the Imperial Academy of Sciences designed to rid it of pseudoscientists and to bring science into closer contact with the needs of practice. Timiryazev vigorously advocated an ideological and organisational alliance of labour and science. Much attention to the role of scientific schools in the continuity of knowledge was given by Lebedev, Zhukovsky, Zimin, Chaplygin and other scientists.

Vernadsky did much to work out various aspects of science organisation and administration. In his writings from 1910 to 1917, he considered various problems in the evolution of science institutions in the light of the dependence of the forms of science organisation on the character and functions of science. He was one of the first to put forward the idea of pursuing a policy in the field of science, which was a problem of the relationship between science and the state. The editor-in-chief of the journal *Priroda* (Nature), N. K. Koltsov, wrote much about the place of science organisations within the system of state institutions, the forms and methods of scientific cooperation, and the establishment of a science-information system. The quest for the most rational forms of research was constantly discussed in the reports of the Academy, from 1904 on, with the active participation of

the Permanent Learned Secretary of the Academy of Sciences S. F. Oldenburg.[1]

Just before the 1917 October Revolution, the main idea on science organisation in Russia was that all the scientific personnel should be brought together on a national scale within a network of research institutes. From 1900 to 1917, 114 new science organisations were set up in Moscow and Petrograd, but more than 90 per cent of them were science societies and departmental and interdepartmental science committees and commissions. Only 2.6 per cent were research institutes, and even these owed their origination to public or private initiative. Among them, the Technical Sanitation Institute was financed by the Society for the Improvement of Cities, while the Litogaea and the Top Soil and Subsoil Institutes were endowed by private benefactors.[2]

The tsarist government made no effort to extend or modernise the country's science network and, in fact, took a suspicious view of any public initiatives in this field. Thus, the Association of Russian Natural Scientists and Physicians, whose establishment had been proposed back in 1869, received official sanction only in 1910, while its statute was approved only in 1916. In vain did Vernadsky say: "The state should make available the necessary funds and increase the budget of public and government science organisations engaged in the study of natural productive forces; it should organise a balanced and systematic study of the productive forces over the next few years." The project for a Lomonosov Institute under the Academy of Sciences as a centre of natural science research in the country remained on paper, because the government did not appropriate the necessary funds. Moreover, the Imperial Academy of Sciences itself received 47,000 rubles a year, dragging out a miserable existence, while appropriations for the "science enterprises" of all the science societies in the country came to no more than 40,000 rubles a year. [3]

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[1] *Organisation of Scientific Activity,* Moscow, 1968, pp. 154-55 (in Russian).

[2] Ibid., p. 159.

[3] Ibid., pp. 179-80. Meanwhile, upon its foundation the Kaiser Wilhelm Society received 11 million marks from the German Government and 7.5 million from industrialists (ibid., p. 162).

The science network in Russia was not developed to any appreciable extent. It consisted of only 105 institutions of higher learning and under 300 other science establishments, mainly small laboratories, experimental stations, and so on, employing less than 12,000 scientific workers. [1] The country's leading science establishment—the Imperial Academy of Sciences—had only 52 science institutions (laboratories, museums, commissions, committees, and stations) employing a total number of some 265 persons. [2] Neither the Academy of Sciences nor any of the other science organisations were able to coordinate scientific research on the scale of the whole country, while the few science establishments were highly dispersed. Because of tsarist Russia's general technical and economic backwardness, scientific activity had scant connection with the needs of production, and the government did nothing to right this. Meanwhile, basic theoretical research developed with some success, creating a rich scientific "reserve" for the future. But any scientist daring to attack the pillars of "autocracy, orthodoxy and nationality" was expelled from the Academy of Sciences and the universities, excommunicated from the Church, exiled and subjected to police supervision and harassment.

What we should now call the infrastructure of science in Russia was in an extremely primitive state. Even Lebedev's famous physical laboratory was housed in very small and unsuitable premises. Scientists had to equip their laboratories at their own expense, and frequently at home. The science libraries network was embryonic. Public education was in a very sad state. Up until the October Revolution, Russia had one of the worst literacy records in the world, and this drastically hampered the training of scientific personnel, especially among the non-Russian nationalities of the Russian Empire.

The Great October Socialist Revolution and the establishment of Soviet power worked a radical change in the socio-political conditions for the development of the productive forces, including science. For the first time

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[1] *The Land of Soviets over 50 Years*, Moscow, 1967, p. 276 (in Russian).

[2] *Organisation of Scientific Activity*, pp. 213, 215.

in mankind's history, a practical start was being made in implementing the goals of scientific socialism and building a new social system on the basis of science. That is what made Russia the homeland of policy in the field of science as one of the key functions of the new type of state. The RSFSR's first People's Commissar for Public Education, Anatoly Lunacharsky, wrote: "There is a profound and fundamental connection between science and the revolution. It is so great that the differences which emerged were no more than superficial and transient." [1]

In its very first months, the Soviet government acted on the premise that the future of science and of socialist construction was indivisible. A report prepared by the Science Department of the People's Commissariat for Public Education for the 1917-1919 period emphasised: "Science is the basic, mighty and omnipotent instrument and fundamental mainstay of socialist state construction, its progress and successful advance. Scientific knowledge, the scientific world outlook, which has spread deeply among the masses of people, is one of the fundamental and necessary conditions and instruments of sound, stable and genuine socialism.

"Science, regarded from its humanitarian and social aspects, has the lofty and immense task of bringing about a radical recreation and remodelling of society, of its very system and structure. Science, regarded from its natural historical and polytechnical aspect, has the honorary and invaluable task of transforming ... the material environment, and raising it to a level under which the loftiest aspirations of the human spirit would be achieved." [2]

The close connection between science and the cause of socialism is the fundamental principle of Soviet policy in the field of science. Lenin wrote: "Socialism ... is founded on the sum-total of human knowledge, presupposes a high level of scientific development, demands scientific work, etc., etc." [3]

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[1] See, *The Organisation of Science in the Early Years of Soviet Power,* Collection of Documents, Moscow, 1968 (in Russian).

[2] Ibid., p. 33.

[3] V. I. Lenin, "A Letter to the Northern League", *Collected Works,* Vol. 6, p. 163.

This principle was consistently expressed in Lenin's "Draft Plan of Scientific and Technical Work", which set before the Academy of Sciences—totally out of touch with practical matters before the revolution—the task of studying the country's productive forces and moving industry closer to the sources of raw materials. [1]

That is the basis on which work was started, on Lenin's instructions, on the famous GOELRO Plan, which was the prototype of long-term prognostication and planning of scientific and technical progress. This approach was also applied to the formulation of the initial strategy for the development of Soviet science.

Let us bear in mind that this was a field where everything had truly to be started from scratch. No country in the world, including even those which had far outstripped Russia in technico-economic terms, had ever set itself the task of planning science.

In the tackling of the most vital and urgent tasks in organising the work of the state apparatus, electrifying the country, wiping out illiteracy, and so on, the young Soviet state was also laying the foundations for a new and modern infrastructure of scientific and technical progress and the mechanism for administering it. In extremely arduous conditions—a fierce famine, economic dislocation, counter-revolutionary resistance—the young Soviet state necessarily had to start not with the "cell" but with the "brain", with the establishment of a system of agencies to direct scientific activity. It did set up such a system together with the state apparatus.

On November 9 (22), 1917, the All-Russia Central Executive Committee and the Council of People's Commissars issued a Decree on the State Commission for Education, which had the duty to formulate state policy in the field of education, science and culture. The idea was that it should set up a Science Department—the first in Russia, or anywhere else in the world, for that matter—as an agency for the state direction of science. It was to oversee the Academy of Sciences, the institutions of higher learning, science societies, libraries, museums, archives and other science institutions.

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[1] V. I. Lenin, "Draft Plan of Scientific and Technical Work", *Collected Works,* Vol. 27, pp. 320-21.

A circular issued by the Science Department of the People's Commissariat for Public Education said: "The political and social revolution through which the country is now going sets the task of bringing science closer to the practice of life. The urgent task just now is to introduce scientific experience in every field of popular labour as a matter of working practice, and to illumine the creative endeavour of the practical working people with scientific thought. Everywhere, in the socio-economic field, in the field of labour organisation and of raising its productivity, and in the practice of social labour education—one feels an insistent need to build and create on the vivifying basis of scientific knowledge."[1]

But if this task were to be fulfilled, Russian scientists and other intellectuals had to break most resolutely with the old mentality and world outlook. It took tremendous efforts on the part of the proletarian dictatorship to win over the intelligentsia for socialism, and to consolidate and organise the country's scientific forces.

Soviet power "had at once to confront the incredible chaos in the field of scientific work. The revolution inherited from the old regime a lack of organisation among men of science and of science itself; first, the absence of any planned promotion of scientific work, and second, obtrusive tutelage on the part of the government authority." [2] It was obvious that science could be mobilised for the service of socialist construction only through its own planned organisation, and this was something that had not yet been done anywhere in the world. Here, a real trail had to be blazed. The circular added: "The next task is not only to bring practice and science closer together, but also to draw scientific workers into closer contact with each other. As almost everywhere, our scientific forces are dispersed, our scientific efforts uncoordinated, men of science unorganised. Scientists have been working independently of each other, to the best of their ability, energy and talent, frequently unaware of whether the same problem is being tackled by other specialists among their colleagues. There is no agency to collect, record and catalogue all the results of scientific endeav-

[1] *The Organisation of Science in the Early Years of Soviet Power,* p. 31.

[2] Ibid., p. 28.

our, and so help workers in science and practice make appropriate use of the results of completed projects.

"In view of this, a vital need just now is to establish organisational links between the disconnected efforts and bring into a system the results of scientific work in all its fields."[1]

The Soviet government had to start by creating elementary conditions for rehabilitating and developing scientific life and establishing order and providing food rations for scientists. We must note the efforts to put this matter on a scientific basis as well. On instructions from the Commissariat for Food Supplies of the North-Western Region, Professor of Hygiene of the Military Medical Academy, G. V. Khlopin, Professor of Physiological Chemistry of the same Academy, M. D. Ilyin, and senior assistant at the Hygiene Department, Y. L. Okunevsky, worked out a set of considerations on the desirable ration for scientists, which were certified by Professor V. N. Tonkov. In accordance with their recommendations, scientific workers were allowed an "academic ration" of 3,539 calories, which was slightly less than the frontline Red Army ration of 3,785 calories, and for members of their families, a ration of 2,566 calories, which was the same as the Red Army ration for the rear. [2] The most outstanding specialists were released from "any kind of services (labour, military, etc.), which were irrelevant to their scientific knowledge". It was also decided to "provide housing conditions for these specialists' scientific work to ensure the minimum conveniences unquestionably required for such work". [3] A decree issued by the Central Commission for Improving the Everyday Conditions of Scientific Workers, set up under the Council of People's Commissars, also made arrangements for supplying scientific specialists with consumer goods. [4]

A differentiated approach was practised to the distribution of the modest stocks of vital goods then at the disposal of the Soviet state. [5]

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[1] Ibid.
[2] Ibid., pp. 341-42.
[3] Ibid., p. 340.
[4] Ibid., p. 341.
[5] Ibid., p. 346.

Let us emphasise that the material incentives held out by the workers' and peasants' state to scientists were also of moral significance, being evidence of the recognition of the vital importance of their work on a national scale. This applies especially to the prizes which were offered to the "workers in the field of science who were most necessary for the Republic" from 1922 on.[1] It was established that prizes would be paid for scientific, scientific and academic, and popular-science works for their 1) originality, 2) topicality, 3) practical usefulness and 4) fast completion, and in addition, for scientific and academic, and popular-science works containing fresh factual material and written in a clear and well understandable style. These works were to be assessed on a five-point system.[2] A 1925 decision envisaged that scientific works on any subjects would be eligible for such prizes, and that the size of the prizes was to be increased, with the time taken to produce such works also being taken into consideration apart from their scientific qualities. When Lenin, the founder of the Soviet sttae, died, a prize named after him was established for the "best works in every field of knowledge of great and vital importance".[3] These prizes became the highest form of recognition and encouragement for scientific achievements in the country.

The Soviet Government's concern for normalising the scientists' working conditions was a key motivation for their efforts.[4] This was subsequently formalised in a decree issued by the Council of People's Commissars on

[1] *The Organisation of Science in the Early Years of Soviet Power,* p. 345.

[2] Ibid., p. 362. In prerevolutionary Russia rewards for scientific and technical achievements were casual and individual. Thus, in 1892, N. G. Slavyanov, who invented an electric welding apparatus, was awarded a medal and an honorary diploma by the Russian Technical Society, and also won prizes at the World Fair in Chicago in 1893. However, these moral inducements did not come from the state.

[3] Ibid., pp. 364, 365, 366-68. In June 1925, the RSFSR Council of People's Commissars issued a decree on the award to workers in science and technology of the honorary title of "merited" for especially valuable works, with the right to receive their pensions while continuing in government jobs.

[4] V. I. Lenin, "To the Presidium of the Petrograd Soviet", *Collected Works,* Vol. 35, p. 460.

January 16, 1922, "On Measures to Improve Housing Conditions for Scientific Workers". With the establishment of research institutes under the USSR Academy of Sciences, and under the Science and Technology Department of the Supreme Economic Council and other departments, they were either installed in the best premises or had new ones urgently built for them. Despite the paucity of the foreign-exchange reserves, the government made appropriations for the purchase of modern scientific equipment and instruments abroad. The Commission for the Improvement of Everyday Conditions for Scientists was instructed "by agreement with the departments concerned to lay down procedures for the supply to scientific workers of publications from abroad", and this was backed up with a foreign exchange fund. In June 1921, a Foreign Literature Committee was set up by a decree of the Council of People's Commissars under the People's Commissariat for Public Education as the central interdepartmental body charged with the purchase and distribution of foreign literature in every field of knowledge for provision to libraries, scientific institutions and individual scientists. A great deal in this matter was done by Lenin, then Chairman of the Council of People's Commissars.[1]

In the very difficult conditions of the period, everything was being done to help the leading Russian scientists in their creative endeavour. Thus, a government decree issued on the 50th anniversary of Professor Zhukovsky's scientific activity released "the father of Russian aviation" from the duty of lecturing, with the right of presenting courses "of a more important scientific content". He was given a personal salary, and an annual Zhukovsky Prize was established for the best works in mathematics and mechanics. A decision was taken to publish his works. Another decree issued by the Council of People's Commissars took account of "Academician I. P. Pavlov's absolutely exceptional services, which are of tremendous importance for the working people of the whole world" and authorised a special commission, headed by Maxim Gorky, "to create within the shortest possible

[1] *The Organisation of Science in the Early Years of Soviet Power,* p. 347. Simultaneously, by agreement with the departments concerned, simplified procedures were laid down for the issue of permits to scientists travelling abroad.

period favourable conditions for backing up the scientific work of Academician Pavlov and his associates". The State Publishing House was instructed "to print at the best printing house of the Republic a deluxe edition of the scientific work prepared by Academician Pavlov summing up the results of his scientific efforts over the past 20 years, reserving for Academician I. P. Pavlov the copyright in this work both in Russia and abroad".[1] When the great physiologist expressed the wish to visit the United States, Lenin gave instructions that a foreign passport should be issued to him "without the slightest delay" and "without any formalities". Although Pavlov was invited to stay in the United States and offered all sorts of benefits, he preferred to return to his native land. When his physiological laboratory was flooded in 1924, Academician Pavlov was at once given new premises to organise a new and larger laboratory, which was converted into a Physiological Institute in 1925. To mark his 80th birthday, a well-equipped institute named after him was built at Koltushi, near Leningrad. In a letter to young people, Pavlov wrote: "Our Homeland opens up great horizons before scientists, and it must be duly said that science is being generously introduced into life in our country. This is being done with the utmost generosity."[2]

Many other outstanding Russian scientists and engineers would have endorsed these words, because it was only the October 1917 Revolution that enabled them to realise their creative plans, and this also applied to those of them who did not at once understand or accept the establishment of the new system. Among those who sided with Soviet power were Professor of the Petersburg Mining Institute A. A. Skochinsky, who subsequently became a member of the collegium of the Supreme Economic Council's Mining Council, and Chairman of the Scientific and Technical Council of the Chief Administration of the RSFSR Mining Industry; the hydroenergy specialist G. O. Graftio, who designed and directed the construction of the Volkhov Hydroelectric Power Plant; the biochemist Professor A. N. Bakh; the remarkable chemist

[1] Ibid., pp. 360-61.

[2] I. P. Pavlov, *Selected Works*, Moscow, 1949, p. 51 (in Russian).

Professor N. D. Zelinsky; the oil geologist I. M. Gubkin; the bridge engineer Y. O. Paton, and many others. The Soviet state's science policy undoubtedly provided the most powerful motivation for scientific workers who had dedicated themselves to building the new society.

All of this first helped to provide a real basis for the consolidation of Russia's scientific forces for tackling general tasks of national importance. The most outstanding Russian scientists—K. A. Timiryazev, V. I. Vernadsky, I. P. Pavlov, and K. E. Tsiolkovsky, among others—decided to work with the Soviet government, and their bold and innovative ideas and schemes were given the practical support which they had been denied both by the tsarist and the bourgeois Provisional governments.

Shaping the Scientific Activity Structure

Establishment of research laboratories and institutes was started in the early months after the revolution, which was an arduous period of war, blockade, famine and economic dislocation. In 1918 alone, 18 new scientific establishments were set up in the RSFSR, and this included major ones like the Platinum Institute, the Ceramics Institute, the Optical Institute, the X-Ray and Radiological Institute, the Central Aerodynamics Institute, the Institute of Physico-Chemical Analysis, the Institute of Applied Mineralogy, and the Central Scientific and Technical Laboratory. From 1918 to 1923, 55 research institutions were set up, and their distinctive feature was concentration on vital applied tasks together with the elaboration of fundamental theoretical problems in the structure of the atom and crystals, spectral and physico-chemical analysis, biophysics and genetics. This helped to materialise the hopes of the best men in Russian science for the *establishment of a state network of research institutions.* [1]

The initial idea was that the Science Department of the People's Commissariat for Public Education was to be the sole extradepartmental agency for directing all scientific activity in the country, but within six months the

[1] *Organisation of Scientific Activity,* p. 179.

inadequacy of the idea had become quite clear. Basic research in which the scientific establishments subordinate to the department specialised, failed to meet the requirements of production, while the sectoral People's Commissariats began to set up their own research units.

To direct these, the Council of People's Commissars issued a decree in August 1918 setting up the Scientific and Technical Department of the Supreme Economic Council with the task of centralising applied research and technical works, to establish links between research institutions and industrial enterprises and economic agencies, to set up specialised science-industrial laboratories and to coordinate their work with the needs of the economy. [1] Towards the end of 1923, there were over 120 scientific institutes and laboratories within the Supreme Economic Council system, which were linked with each other not only through common administrative subordination but also functionally. Simultaneously, similar systems were set up at individual departments (People's Commissariats), including the People's Commissariat for Labour, the People's Commissariat for Communications, the People's Commissariat for Posts and Telegraphs, and the People's Commissariat for the Affairs of Nationalities. By 1925, the network of scientific establishments of the People's Commissariat for Public Health comprised eight major institutes (Control of Vaccines and Serums, Social Hygiene, TB, and others) within a single system of the State Institute of Public Health. [2] A complex of social science establishments and science societies under the Communist Academy for the Social Sciences, which was subordinate directly to the All-Russia Central Executive Committee of the RSFSR, took shape as an independent system.

The resultant system for directing scientific activity in the country proved to be sufficiently decentralised to ensure the necessary diversity. In connection with the reorganisation of the Workers' and Peasants' Inspection, Lenin said: "The People's Commissar of the Workers'

[1] *Decrees of Soviet Power,* Vol. III, No. 124, Moscow, 1964, pp. 212-15 (in Russian).

[2] There is much in common between this Institute and the system of National Institutes of Health under the Department of Health, Education, and Welfare in the United States.

and Peasants' Inspection should work on partly amalgamating and partly coordinating those higher institutions for the organisation of labour ... of which there are now no fewer than 12 in our Republic. Excessive uniformity and a consequent desire to amalgamate will be harmful. On the contrary, what is needed here is a reasonable and expedient mean between amalgamating all these institutions and properly delimiting them, allowing for a certain independence for each of them ...." In my opinion we ought to select a minimum "... see whether they are organised properly, and allow them to continue working, but only in a way that conforms to the high standards of modern science and gives us all its benefits." [1] Special agencies were set up within each of the subsystems to ensure coordination of scientific establishments. This was the State Science Council of the People's Commissariat for Public Education which, however, concentrated almost entirely on the higher schools; the Science Commission of the Scientific and Technical Department of the Supreme Economic Council, with its sectoral sections and local branches, employing several hundred staff members, experts and consultants; the Medical Science Council of the People's Commissariat for Public Health; the Agricultural Science Committee of the People's Commissariat for Agriculture, and so on.

The overall direction of scientific activity in the country remained in the hands of the highest organs of legislative and executive power: the All-Russia Central Executive Committee and the Council of People's Commissars, which determined the competence and functions of the departmental agencies engaged in directing science, the limits of the sectoral network of the scientific institutions, the orientation of their activity, financing, and so on. The relatively simple structure of the departmental subsystems made it possible to coordinate their activity with a fair amount of success through cross-cooperation between the heads within the collegiums of the various People's Commissariats, on the science councils, and the State Planning and Financial Commissions, and chiefly on an informal basis. On the research institute and labo-

[1] V. I. Lenin, "How We Should Reorganise the Workers' and Peasants' Inspection"; "Better Fewer, But Better", *Collected Works,* Vol. 33, pp. 484, 492.

ratory level, this coordination was effected by means of regular congresses and conferences in the various fields of knowledge and on the major intersectoral problems. An important form of science activity cooperation was provided by associations of scientific establishments, which were initiated by the Science Department (subsequently Chief Science Administration) of the People's Commissariat for Public Education. But the all-Russia sectoral associations—physics, geophysics and astronomy—set up under its umbrella proved to be less efficient than the fundamental associations of research institutes at the higher schools, social sciences institutes, and so on, and especially the problem commissions, like the Radium Commission, the Atomic Commission under the State Optical Institute, the Commission on Fixed Nitrogen, the Aluminium Commission under the Supreme Economic Council, and so on. These commissions engaged in prognostication, which was done by specialists temporarily assigned to the job on borrowed equipment within the framework of objective-geared estimates.

Following the formation of the USSR in 1922, new science complexes of all-Union, republican and local importance began to develop alongside the functional and sectoral differentiation and specialisation of scientific activity. Scientific organisations of all-Union importance began to spin off from the RSFSR People's Commissariat for Public Education. In 1925, the Council of People's Commissars and the Central Executive Committee of the USSR issued a decree designating the Academy of Sciences as an all-Union establishment, which was then subordinated to the Central Executive Committee of the USSR. A new Statute of the USSR Academy of Sciences was adopted in 1927, inaugurating its transformation into a coordination and methods centre for basic research in the country.[1] Simultaneously, almost all the major technical and natural science institutes were transferred from the People's Commissariat for Public Education to the Supreme Economic Council, the People's Commissariat for Public Health, the People's Commissariat for Labour, and so on. In 1929, the system of scientific establishments of the People's Commissariat for Agriculture provided the basis for the establishment of the V. I. Lenin All-

[1] *Organisation of Scientific Activity,* pp. 226-27.

Union Academy of Agricultural Sciences with 11 Institutes in the basic fields of agricultural science engaged in basic and applied research and development.

As the science organisation system took shape within the framework of other departments, their direction was also switched from the Scientific and Technical Department of the Supreme Economic Council to the scientific and technical councils of the chief administrations and departments, and these tendencies were not reversed either by the establishment of the Central Scientific and Technical Council or the transformation of the Scientific and Technical Department into the Scientific Research Sector of the Supreme Economic Council. There was a deepening differentiation of the hierarchical departmental structures into leading and sectoral research institutes, experimental and industrial laboratories, experimental stations, and so on, within the framework of the People's Commissariats for the Heavy and Light Industries, into which the Supreme Economic Council had been divided, and then also of the numerous People's Commissariats into which the latter were divided. This evolution was kept under control by the October 1931 Decree of the RSFSR Council of People's Commissars, "On Rationalising the Science Institution Network", which then became an all-Union norm. Research centres, the Decree said, were to be strictly subordinate to a given department, and any changes within the scientific network were to be agreed with the State Planning Committee and approved by the Council of People's Commissars. Under a Central Executive Committee Decree in December 1933, the USSR Academy of Sciences was placed under the supervision of the USSR Council of People's Commissars, and this enhanced its science-organisational role. In 1936, the social science institutions of the Communist Academy were also transferred to the USSR Academy of Sciences.

Consequently, the decentralisation of day-to-day administration, especially in applied research and development, went hand in hand with the centralisation of the strategic direction of Soviet science in basic research, and this was on the whole in line, on the one hand, with tradition and, on the other, with the important tasks facing the organisation and administration of science system in the USSR. Thus, the directing system, largely built from

the ground up, was also the structure-formative system, operating as a kind of RNA matrix, setting up research institutes and other scientific establishments according to its own image and likeness. For the first time in history, the spontaneous development of the organisational structure of science had given way to conscious development.

Science Policy Agencies in the USSR Today

A characteristic of the present organisation and administration of science system in the USSR is best begun with a description of the directive agencies which more than ever before have the function of being the "central nervous system" within the organism of scientific activity as a whole.

The leading force of Soviet society—the Communist Party of the Soviet Union—has an important role to play in deciding on the key aspects of science policy, which acquire primary social importance. These have by rights been prominent in the work of the 23rd, 24th and 25th Congresses of the Communist Party, the Central Committee's reports, the reports of the Chairman of the USSR Council of Ministers, speeches by prominent public figures and statesmen, including the Chairman of the State Committee of the USSR Council of Ministers for Science and Technology, the President of the USSR Academy of Sciences, and other workers in science. Constant attention is being given to the development of science and acceleration of scientific and technical progress, and this is reflected in the decrees issued by the CPSU Central Committee and the USSR Council of Ministers on the key aspects of science policy. Thus, in May 1974, they considered the measures to accelerate the development of molecular biology and molecular genetics, and the use of their achievements in the economy. The decree envisages a number of measures to raise the general level and scale of research in molecular biology and molecular genetics in the country, to train highly skilled specialists and to organise the manufacture of special scientific instruments and devices. The State Committee for Science and Technology and the USSR Academy of Sciences were instructed to lay down the main lines of basic research and works in applying the achievements

in molecular biology and molecular genetics in the economy, and also to outline a concrete programme for R & D until 1980. An interdepartmental Scientific and Technical Council was set up to coordinate research in this field. The decree spells out concrete measures to extend the training of scientific and science-teaching personnel, to develop the material and technical facilities of existing and new research institutions, educational establishments, and experimental stations and to supply them with the necessary scientific instruments and equipment, reagents and other materials.

That same month, the CPSU Central Committee issued a decree on enhancing the role of libraries in the communist education of the working people and in scientific and technical progress. It urged the need to extend the activity of scientific, technical and public libraries in spreading scientific and technical achievements and advanced experience, and in speedily supplying scientific and technical information to specialists in the economy. The libraries are to provide differentiated assistance to readers, in accordance with their educational standards, professional interests and age. The CPSU Central Committee instructed the Councils of Ministers of the Union Republics, Party, Soviet government and trade union organs, ministries and departments to take steps further to consolidate the material and technical facilities available to libraries and to see that these are located in a balanced manner. The USSR State Planning Committee was authorised to make provision, when framing the 1976-1980 economic plan, for increasing the manufacture of library equipment, means of mechanisation and copying and duplicating machinery. From 1974 to 1976, the USSR State Construction Committee and the USSR Ministry of Culture were to produce new standard designs for library buildings in various parts of the country.

Alongside the overall direction of science policy on the macrolevel, much attention is being given to the work of the grass-roots scientific collectives at the microlevel, with feedback being enhanced from the mass of scientific workers to the members of governing boards, and the activity of other public bodies invigorated.

Fresh opportunities to enhance the efficiency of

science institutions individually and as a system are opened up through the control exercised by public organisations. These have as their members leading scientists, specialists in production and Party workers. Commissions are usually set up after a review of achievements in a given field on the basis of a representative institute, which then becomes central to the work of the commission. Its concern is to accelerate the "technology transfer" both along the vertical and the horizontal. It makes a study of and sums up the positive experience gained in cooperation between scientists and workers in production and helps to spread it. This is done through exposition seminars at the base institute to acquaint audiences with the substance of various projects and the state of their practical application. This is followed by an effort to bring out the enterprises where it would be advisable to apply such projects. The commissions submit to their managers recommendations and whenever necessary detailed substantiations and explanations.

There are problem and interdisciplinary commissions. They deal with various problems in improving foundry production, heat-transfer processes, wider use of superhard materials, lubricating and cooling liquids, automated control systems in production and the application of scientific projects in electric welding, polymers, metal ceramics, railways and highways, construction, the clothing and footwear industry, and so on. The commissions act as interdepartmental elements because their work bears on the business interests of dozens of scientific and technical institutions and enterprises of different subordination. This is highly important because departmental barriers are among the most intractable obstacles along the path of scientific and technical progress. Thus, the Commission for Foundry Production helped to bring about the rapid application of the latest production techniques developed at two institutes by 15 industrial enterprises in Kiev with different departmental subordination. The Commission on Superhard Materials and Diamonds helped to conclude 29 contracts on creative cooperation, which promoted progressive changes in technology at enterprises in the metalworking, china and porcelain, woodworking, electronic and footwear industries. Representatives of the institutes of automation, petrochemistry,

woodworking and other industries, and of the Kiev Polytechnical and Highway Institutes and other institutions of higher learning have been cooperating fruitfully in the work of such commissions.

From 1971 to 1973, such standing commissions did much to boost labour productivity in Kiev's industry by 20.7 per cent, as compared with the target of 15.1 per cent. The development of this activity led to the establishment of a Kiev Scientific and Technical Council to deal with problems in developing production, the urban economy and protection of the environment, and to help control fulfilment of thematic plans by research institutes on these problems.

Similar commissions and interdepartmental councils are also being set up in other cities of the USSR.

In the country's supreme legislature, the functions of control by deputies over the formulation and implementation of science policy are exercised by standing commissions of the Soviet of the Union and the Soviet of Nationalities of the USSR Supreme Soviet for public education, science and culture. Meeting separately and jointly, these commissions hear reports by chiefs of ministries and departments on their efforts in directing scientific and technical progress. The commissions are elected at the first session of every new Supreme Soviet and consist of 35 deputies, among them workers in science, education and culture, industrial workers, collective farmers, industrial executives, Party functionaries and Soviet government officials, representing all Union and many autonomous republics. Within the competence of these commissions is the formulation of proposals for consideration by the corresponding Chamber or the Presidium of the USSR Supreme Soviet, findings on matters presented for their consideration, assistance to agencies of the executive power in fulfilling the decisions of the legislative power, and control over their implementation. These commissions meet on average twice a year, and each session is preceded by long and thorough preparation by a group of deputies specifically set up for the purpose. Such groups include representatives of the ministries, departments, government and public organisations and scientific institutions concerned, and specialists and scientists. The commissions of both Chambers have equal duties and

powers, including that of legislative initiative. The more important and time-consuming matters are considered jointly by the commissions of the Soviet of the Union and the Soviet of Nationalities, while matters of state importance are dealt with by several commissions of either or both Chambers. Some six or eight weeks before the Supreme Soviet meets for its consideration of the annual economic plan indicators and the Budget of the USSR for public education, science and culture, a joint preparatory commission is set up, and includes members of the planning and budget commissions and the commissions for the affairs of young people of both Chambers, an approach which helps to concert the interests of the individual sectors and the overall state interest and to find additional reserves. Thus, from 1971 to 1974, the commissions helped to increase the budget for socio-cultural measures by 274 million rubles.

The USSR Council of Ministers, the highest organ of executive power, exercises the chief functions in the strategic and operational direction of scientific and technical development. Today, one will hardly be able to find any sector in the activity of the USSR Council of Ministers that is not directly or indirectly connected with scientific and technological matters. The decisions of the 25th Congress of the CPSU are designed "to concentrate the attention of scientists on crucial problems connected with scientific, technical and social progress, on the solution of which largely depends the successful development of the economy, culture and science itself". They envisage, "the further development of research which opens up essentially new ways and possibilities for transforming the country's productive forces, for developing the machinery and technology of the future". [1]

A special responsibility for fulfilling science policy tasks falls mainly on three agencies of the Union Government: the State Committee of the USSR Council of Ministers for Science and Technology, the State Planning Committee of the USSR Council of Ministers, and the USSR Academy of Sciences, which is directly subordinate to the Council of Ministers. While the USSR Academy of Sciences, the highest centre of theoretical research, coor-

[1] *Documents and Resolutions. XXVth Congress of the CPSU*, p. 231.

dinates the whole of scientific activity in the country, the State Planning Committee plans the use of scientific and technical achievements in the economy, while the State Committee for Science and Technology directs the development of science and technology as a whole by putting through a coherent state science and technology policy.

The State Committee of the USSR Council of Ministers for Science and Technology lays down the guidelines of scientific and technical development in the country, organises the elaboration of intersectoral scientific and technical problems, sees to the enhancement of the efficiency of research and the rapid use of its results in the economy, and organises the flow of scientific and technical information and international cooperation in science and technology. It gives technico-economic evaluations of the level of scientific and technical development in the various industries and takes steps to speed scientific and technical progress and develop the scientific organisation of labour in the country. For that purpose, and together with the USSR Academy of Sciences, ministries and departments, it selects the most promising results of basic research, arranges for their development in the sectoral research institutes and design offices, and maps out the fields and modes of application of these developments to production. The Committee devotes special attention to controlling the timely introduction of achievements in science and technology which are most important from the standpoint of the economy as a whole.

Indeed, the Committee's structure is geared to these tasks. Its Chairman is a Deputy Chairman of the USSR Council of Ministers, a member of the CPSU Central Committee, and a full-fledged member of the USSR Academy of Sciences. The Committee's work is collegial. Its decisions are taken by a collegium, on which are represented not only members of the Committee but also authoritative members of the USSR Academy of Sciences, ministries and departments. The Chairman of the Committee and his deputies are in charge of departments and functional administrations, and also of an integrated scientific and technical planning department. Science councils for the main complex and intersectoral problems have an important part to play in the Committee's activity. These are consultative bodies on which more

than 5,500 members of councils and their sections work on a no-payroll basis, including 160 academicians and corresponding members of the USSR Academy of Sciences, and almost 1,000 doctors of science and 1,600 candidates of science. These councils hear and discuss reports by the heads of the technical administrations of ministries and departments, directors of institutes and scientists on the state of work on various problems in the USSR and abroad. They map out the guidelines of research for the speediest solution of various problems, formulate recommendations on ways for the practical use of the results obtained and the latest scientific and technical achievements, and on winding up dead-end projects. Clearly, such matters cannot be settled by purely administrative means, so that the councils have an especially important part to play as organs of scientific expertise. In their activity, these councils establish a great many formal and informal contacts with the science councils of the USSR Academy of Sciences (many leading scientists are simultaneously members of both) and also with the scientific and technical councils of ministries and the corresponding sectoral departments and administrations of the State Committee of the USSR Council of Ministers for Science and Technology.

The Statute on Science Councils for the Key Complex and Intersectoral Scientific and Technical Problems (No. 37 of February 26, 1966) says that the councils are consultative organs whose task is to analyse progress in elaborating comprehensive scientific and technical problems, to decide on the main lines of development and to draw up consolidated plans as recommendations for the directive bodies. An analysis of the work of these science councils shows that most of them are engaged in coordinating work in individual fields or topics.

Soviet writers have pointed out that comprehensive plans are designed to range over the "research-production" cycle and set strict limits on their sources of financing.

There is no excessive centralisation in the overall and day-to-day direction of the intersectoral scientific and technical programmes. The State Committee for Science and Technology is the central organ of administration,

allocating the science funds among the ministries and departments in accordance with programme priority. However, these are financed by the ministries and departments, which have the leading part to play in implementing these programmes. [1]

An important aspect of the work of the State Committee for Science and Technology is the spread of advanced scientific and technical experience and arrangement of an efficient system for the supply of scientific and technical information. Today, this kind of horizontal technology transfer is as important as—frequently more important than—vertical transfer, from the origination of the new idea to its engineering. There is little benefit to be had from reducing the "science-production" cycle if the latest scientific and technical achievements are applied at one enterprise, or even in one industry, without being transferred horizontally in good time. Here, the Committee is helped by its subordinate the USSR Exhibition of Economic Achievement, the Association for the Direction of Scientific and Technical Information and Propaganda of the RSFSR, the All-Union Scientific and Technical Information Centre, the All-Union Institute of Scientific and Technical Information, and the State Public Scientific and Technical Library of the USSR.

The Chief Committee of the USSR Exhibition of Economic Achievement, together with the Committee regularly arranges contests for the best solution of the key scientific and technical problems and gives awards to the winners in the form of medals, diplomas and cash prizes. The Exhibition has been doing a great deal from day to day in spreading advanced experience and new ideas in science, technology and production among representatives visiting Moscow from all the republics, territories and regions of the country. The pavilions at the Exhibition are specialised according to economic, scientific and technical sectors, and visitors are offered lectures, seminars and film shows.

The State Public Scientific and Technical Library is the chief scientific and technical library of the USSR, a centre of information in library services, which is sup-

[1] Y. V. Kosov, G. K. Popov, *Administration of Intersectoral Scientific and Technical Programmes.*

plied with the main periodicals and nonperiodical publications in every branch of technology and the technical sciences, the physico-mathematical, geological and other sciences, and also on concrete economics, published at home and abroad. In 1970 it had over 6.5 million printed units, including more than 2 million unique specialised funds of scientific and technical literature, Soviet and foreign industrial catalogues, and electronic-computer algorithms and programmes. The library has been doing a great deal to develop methods and bibliographical work, and has also filled orders for the making of microfilms, photostatic copies, and so on, of the publications at its disposal. It has an important role to play in developing the scientific and technical library network.

In May 1974, the Soviet Union had 360,000 libraries with a book stock of 3,300 million copies, and a readership of over 180 million. Scientific, technical, special and public libraries make a point of broadly spreading scientific achievements and advanced experience, providing workers in science and production with information and bibliographical services. The links between the libraries and scientific and technical information agencies are being strengthened. For the purpose of further enhancing the science-information role of libraries, an effort is being made from 1974 to 1980 to centralise state public libraries through the establishment of a single network with a common staff, book stock, centralised supply and processing of literature on the basis of city and district libraries. Simultaneously, ministries and departments, and the All-Union Central Trade Union Council have the duty to work out measures for centralising their own library network, providing for the establishment both of sectoral and interdepartmental centralised systems and ensuring their smooth interaction. The State Committee for Science and Technology, ministries and departments also have the duty to enhance the role of the information agencies and their libraries in coordinating the work of establishing consolidated reference and information funds. To rationalise book-stock organisation at scientific and regional libraries, and their more rational distribution among the country's main economic areas, books which have been in little use since their publication are to be handed over for storage in a limited number to depository libraries.

The Lenin State Library of the USSR and the State Public Scientific and Technical Library of the USSR (for scientific, technical, and special libraries) are to play a growing role as all-Union science-methods centres.

The State Committee for Science and Technology, together with the USSR Ministry of Culture, by agreement with the departments concerned, have the duty to work out the guidelines in the development of libraries across the country, of common principles in locating the network of libraries, drawing up instructions regulating the activity of libraries of different departmental subordination. They also have the duty to approve a list of the depository libraries of all-Union, republican and interregional importance.

The All-Union Scientific and Technical Information Centre has the chief role to play in organising specialised information in the field of science and technology, including sectoral and departmental information. It is to have the safekeeping of candidate's and doctoral dissertations which have been maintained in science and technology, reports on fully or partially completed research and development, and so on.

The Centre has the duty to exchange information on the results of research among scientific institutions, design and development organisations, and enterprises through a study of research reports, including—and this is especially important—unpublished sources. It publishes *Collections of R & D Reference Articles* giving a concise characteristic of the work performed or of complete stages, and also doctoral and candidate's dissertations. By 1970, the Centre had registered 74,000 completed research projects. It publishes a *Bulletin of R & D Registration* listing the planned research projects and indicating the organisers and performers. The *Bulletins* are published in the biology, economics and other series and are available by subscription to the institutions concerned. [1]

The All-Union Institute of Scientific and Technical Information is a supplement to the Centre, being engaged in the collection and initial analysis not only of specialised, but of general information in science, technology and

[1] E. A. Novikov, V. S. Yegorov, *Information and the Researcher,* Leningrad, 1974, pp. 152, 163-64 (in Russian).

economics. It is of dual subordination—to the State Committee for Science and Technology and the USSR Academy of Sciences—and caters for the information needs of fundamental and applied science and of production. The Institute publishes the main *Reference Journal* of the USSR in the form of periodical (monthly) consolidated volumes in various fields of science and technology containing the relevant indexes. Thus, the *Reference Journal, The Economics of Industry*, includes a section on the organisation and financing of research programmes. The material of every consolidated volume is presented in similar narrowly sectoral issues. The *Reference Journal* is a medium of information about new scientific and technical achievements and also provides an information-search system for locating sources on various problems. It contains information from 18,000 journals in more than 100 countries. [1]

There are also *Express Information* (48 volumes a year) and other publications, including *Signal Information* (24 issues a year), the monthly *Scientific and Technical Information*, survey collections, *The Results of Science, The Results of Science and Technology* with bibliographical annexes, and also a series of thematical card indexes.

The USSR is to establish an Integrated State System of Scientific and Technical Information, with the State Committee for Science and Technology and its scientific and information institutions having the leading role to play in elaborating and realising the system. This will help sharply to improve the use of electronic computers and the efforts of the growing number of men and women employed in the provision of information services for science, technology and production. The Integrated System is to be linked up not only with the local and regional computing centres and information agencies, but also increasingly with the automated control systems, so ultimately producing a master-system that should become the basis of scientific administration of the economy and of scientific and technical progress itself, making it possible rapidly and fully to translate the latest achieve-

[1] Every year it is estimated to publish something like one million items on the world scientific and technical literature (E. A. Novikov, V. S. Yegorov, op. cit., p. 152).

ments in fundamental science into the idiom of practice. This is obviously a very intricate task. After all, a doubling of existing production requires a quadrupling of the volume of processed information.

It is natural, therefore, that the Guidelines for the Development of the National Economy of the USSR for 1976-1980, as adopted by the 25th Congress of the CPSU, provide for improvements in scientific and patent information. [1] This entails timely and systematic transfer to the enterprises and associations concerned of the data on scientific and technical achievements and advanced experience in the field of science, technology, and the organisation of production and management. On the basis of the state information system, a coherent technical policy is worked out and implemented with emphasis on the shaping of science-production complexes. Work is being carried on to establish and start automated control systems for sectors, territorial production complexes, production and science-production associations, and individual enterprises, production techniques, territorial organisations, ministries and departments. From 1966 to 1975, 2,742 automated control systems were established at various levels throughout the country. At present, automated control systems for planning computations, state statistics, the State Bank of the USSR, the State Standards Committee of the USSR, the State Committee for Science and Technology, and other systems of statewide importance are being set up. [2]

The existing state system of scientific and technical information in the USSR already comprises 10 all-Union, over 160 sectoral, republican and territorial institutes or centres, and about 9,000 information departments and offices at enterprises and other establishments. They have a stock of over 1,000 million reference information units reflecting the achievements in science, technology and advanced experience. Electronic computers, microfilm devices and electrographic copying devices are used in the search, collection, processing, storage and transmission of information. The task is steadily to make it purposeful,

[1] *Documents and Resolutions. XXVth Congress of the CPSU,* p. 231.

[2] *The USSR in Figures in 1975,* Moscow, 1976, p. 73 (in Russian).

and to differentiate its transfer in the light of the needs of every scientific institution, enterprise and consumer in general. The USSR Council of Ministers has put the duty on all the country's information services annually to submit to the planning agencies, ministries, departments and heads of enterprises information on the most important Soviet and foreign achievements in the formulation and consideration of economic development plans. Mandatory state registration is being introduced not only for finished, but also for ongoing experimental design projects. The ministries and departments, the USSR Academy of Sciences and the Councils of Ministers of the Union republics have been authorised to control the uninterrupted and timely flow of such information. Automated subsystems for collecting, processing, storing and transmitting scientific and technical information are being coupled with automated control systems in production. Such a combined system is already in operation, for instance, in instrument making. [1]

The State Planning Committee of the USSR has the central role to play in the guidance of the USSR's economy on the basis of scientific and technical achievements. Its main task is to work out, in accordance with the CPSU Programme and the Decrees issued by the Party and the Government, plans ensuring the proportional development of the Soviet economy, its steady growth and higher efficiency of social production. A most urgent task just now is to enhance the planned regulation of processes in the practical realisation of scientific and technical achievements. The State Planning Committee has been laying ever greater emphasis on planning the use in the economy of scientific and technical achievements, the manufacture of technically perfect products, the mastery of advanced production techniques, comprehensive mechanisation and automation of production, the use of economico-mathematical methods, computers and automated planning and control and information processing systems. It also exercises control over the fulfilment of these plans and, together with the USSR Academy of

[1] Concerning the quantitative and qualitative growth of the role of information in socio-economic development, see the book: V. G. Afanasyev, *Social Information and the Governance of Society*.

Sciences, organises economic research in the relevant fields.

The Soviet Union's system of planning scientific and technical progress includes a complex of inter-related plans which are framed at various levels of administration and differ in duration, content and amount of detail in which targets are formulated. Long-term (10-15 and more years) scientific and technical prognoses provide the basis for five-year plans (which are basic), and the latter, the basis for current (annual) plans.

Prognostications on the key scientific and economic problems of a general character are drawn up by the State Committee for Science and Technology, the State Planning Committee and the USSR Academy of Sciences with the participation of the ministries and departments concerned. Scientific and technical prognostications on sectoral problems are produced by ministries and departments on their own. This makes it possible to determine the guidelines for the development of science and technology and to identify the most important problems which serve as the starting point for framing the five-year plan.

State five-year plans for research and the use of scientific and technical achievements in the economy are an important component of the state five-year plans for economic development, which are approved by the government. These include targets in solving the key scientific and technical problems and ploughing achievements in science and technology into the economy, financing research and training scientific personnel. Coordination plans are also framed for solving the key problems which are spelt out in detail for the sectors and organisations. Finally, these plans, for their part, provide the basis for current (annual) planning of scientific and technical progress from the countrywide level to the individual research institute, design office and enterprise. [1]

The acceleration of scientific and technical progress is closely dependent on the activity of inventors and rationalisers, the men and women who keep it moving. The Statute on Discoveries, Inventions and Rationalising

[1] See, B. F. Zaitsev, B. A. Lapin, *Organisation of Scientific and Technical Progress Planning*, Moscow, 1970 (in Russian).

Proposals of August 21, 1973, said that the planning of inventions and rationalising activity has the aim of directing the creative efforts of inventors and rationalisers upon the solution of urgent problems in improving social production, securing the timely and extensive use in production of effective inventions and new ideas, developing technical creativity among the working people and involving them in active inventive and rationalising endeavour.

The planning of inventive and rationalising activity should be preceded by a study of the guidelines in the development of science and technology, of Soviet and foreign inventions, advanced technical experience and scientific and technical problems whose solution could make for greater efficiency in social production. [1]

There is an even greater need for scientific back-up in planning the activity of research and development organisations.

The realisation of plans for scientific and technical development accounts for something like 40 per cent of national income growth in the USSR. [2]

Many important scientific and technical problems which are of an intersectoral and territorial character require the participation of more than one ministry or department—each of which has a different stake in the project—with the recruitment of research, development and other establishments. It is the task of objective-geared programme planning and management to bring together within the framework of a single system the measures designed to enhance the efficiency of scientific and technical progress and production not only at the sectoral but also at the intersectoral and republican level. With the availability of the ACSs, the economic management agencies link up, via the peripheral incoming and outgoing information channels, with the computing centres of the planning and accounting agencies and sectoral manage-

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[1] See, *Statute on Discoveries, Inventions and Rationalising Proposals,* No. 584 of August 21, 1973, Moscow, 1973, p. 24 (in Russian).

[2] *Proceedings of a Conference-Seminar on the Use of the Objective-Geared Programme Principle in the Planning and Management of Scientific and Technical Progress,* Vilnius, 1972, p. 53 (in Russian).

ment agencies, with the regional computing centres of associations and enterprises, research institutions and higher schools. The sequence of the operations is set by the "objective-problem-programme-plan" scheme, in accordance with which, for instance, Lithuania's plan for scientific and technical progress from 1971 to 1975 was worked out. In order to develop and coordinate comprehensive programmes for the key intersectoral scientific and technical problems a Republican Council for Intersectoral Scientific and Technical Problems was set up under the Lithuanian State Planning Committee. The coherence of planning and management in making production and scientific and technical progress overall more efficient is secured, on the one hand, through effective organisational link-up between the factory, firm and sectoral branches of science and the services they provide for production, and on the other hand, by a unified system of evaluation and planning economic efficiency of production and scientific and technical progress. For these purposes, large enterprises set up a single service for the comprehensive planning and management of scientific and technical progress, which is directly subordinate to the chief engineer.

In the 1970s, the Latvian State Planning Committee started to make use of finished projects and to control their implementation. At the same time, it helped research institutes to complete their R & D projects in due time, and this went hand in hand with higher demand both on the sectoral research institutes and design offices, and on the institutions of the Latvian Academy of Sciences. An inventory was made of the most important completed R & D projects which had yet to be fully applied in the economy. An evaluation of their potential importance and effectiveness helped to bring out the industries and enterprises where the application of their results appeared to be the most advisable. The most important and completed R & D projects were then card-indexed to provide information for interested institutions and enterprises and also to organise their introduction and control of the process. The sectoral departments of the Latvian State Planning Committee have the duty to verify, at least twice a year—before the framing of the new technology plan and during its adjustment—the progress in application. One copy of the card index is kept

at the Science and New Technology Department, which controls the process of application together with the developer institute and the organisation introducing the project. Every two or three years, the State Planning Committee calls a conference of scientists and workers in production to bring out their mutual interests, to identify any bottlenecks, and the potentialities for closer cooperation. Its recommendations are considered at a meeting of the Committee's collegium. Joint science councils are set up at ministries and enterprises. At the Latvian Institute of Scientific and Technical Information daily consultations are held on completed R & D projects. The all-Union ministries and the State Committee for Science and Technology are regularly informed about projects whose significance goes beyond the boundaries of the republic. Instructions have been issued on the promotion of the manufacture of nonstandard equipment and experimental models. Contacts have been arranged with a group in charge of application of complete R & D projects at the Latvian Academy of Sciences, which has a card index of its own. A representative of the State Planning Committee regularly attends meetings of the Presidium of the Academy of Sciences. [1]

Alongside the new Soviet state agencies set up after the October Revolution to direct scientific activity in the country, an important part belongs to the USSR Academy of Sciences, whose 250th anniversary the country celebrated in 1975.

The establishment of national academies of sciences in Russia, other countries of Europe and in North America was something of a response to the deepening differentiation and integration of scientific knowledge, and the complexification of the tasks and techniques of research and, to some extent, also of the relations between researchers. Emerging alongside the universities and the scientific societies, the academies of sciences marked a transition to organised science on a countrywide scale. In the Soviet period, the Academy of Sciences has come to play

[1] F. A. Lekhtman, "Concerning Some Elements of the System of Organisation and Control of Application of Complete R & D Projects in the Economy of the Republic". In: *Proceedings of an Interrepublican Scientific Conference on the Economic Questions in Scientific and Technical Progress,* Section I, pp. 125-29.

an unprecedented role as the country's supreme scientific institution.

The USSR Academy of Sciences is the chief agency in directing primarily basic research in the natural and social sciences. It lays down the main lines of research, and coordinates the efforts in this sphere of its own institutes, those of the academies of sciences of the Union republics and the sectoral academies—the Academy of Medical Sciences, the Academy of Pedagogical Sciences, the All-Union Lenin Academy of Agricultural Sciences, the Academy of Construction and Architecture, and others, and also of the institutions of higher learning and the leading research institutes of the various departments. The basic tasks of the USSR Academy of Sciences are to develop research along the main lines in the natural and social sciences, exploratory research to promote scientific and technical progress in electrification, comprehensive mechanisation and automation of production, chemicalisation of the economy, use of new energy sources and new methods for energy conversion, fundamentally new lines of technical progress and recommendations for their use in the economy, study and generalisation of the achievements in world science and promotion of their fullest use in the practice of communist construction.

The highest organ of the USSR Academy of Sciences is its General Meeting, which is called at least once a year and is attended by all the full-fledged, honorary and corresponding members. The Presidium handles all the organisational work and provides the day-to-day guidance in the activity of the Academy's divisions. The Presidium consists of the President, the Vice-Presidents, the chief learned secretary, the academic secretaries of the departments and other members of the Presidium, whose number is established by the General Meeting. The Presidium calls the General Meeting, approves, in coordination with the State Committee for Science and Technology and the USSR State Planning Committee, the plan of works in the natural and social sciences, sets up science councils for the key comprehensive problems, decides on the line of activity and specialisation of the institutes, and takes steps to ensure the use of scientific results in the economy. The Presidium also directs the

activity of the academies of sciences of the Union republics through its Coordination Council.

The Academy has 16 departments which are grouped together in four sections (three natural science and one social science section). The departments are scientific and science-organisational centres for one or more branches of science providing scientific and methods guidance to the institutes concerned. The highest organ of the department is its general meeting, and in-between general meetings, the bureau which is headed by an academic secretary.

The Academy's branches and science centres in the autonomous republics, territories and regions have their own leadership (presidia) and their activity is coordinated by the Presidium of the USSR Academy of Sciences. Apart from being subordinate to the Presidium of the USSR Academy, its Siberian Branch is also subordinate to the RSFSR Council of Ministers, and exercises its scientific direction of the institutes together with the corresponding departments of the USSR Academy of Sciences.

Today, as the interval between scientific discoveries and their practical realisation and use tends to shrink, fundamental science has intruded ever more vigorously and fruitfully.

Striking examples of this come from the development of nuclear energetics and semiconductor-based technology, which provides the basis for the modern techniques of management, laser technology, synthetic polymers and microbiological synthesis, fundamental improvement of metallurgical processes, the ever more extensive use of rare elements in industry, and the artificial diamond industry.

The establishment of the Siberian Branch of the USSR Academy of Sciences has been having a direct influence on the development of the productive forces, education and culture in the country's Eastern regions and has led to the emergence of the Far East and Urals science centres of the Academy, the Siberian branches of the All-Union Lenin Academy of Agricultural Sciences, and the Academy of Medical Sciences of the USSR, and also to the extension of the network of institutions of higher learning. Scientists at the Siberian Branch of the

USSR Academy of Sciences have achieved outstanding results in theoretical and applied mathematics and mechanics, nuclear physics and semiconductor physics, quantum electronics, the theory and practice of catalysis, the study of combustion and explosion, in biological research in genetics, and in plant and animal selection. They have been actively working on the theoretical principles for identifying the main types of mineral raw materials.

The basic research carried out at the Siberian Branch has provided the basis for a large number of applied research and development projects. Many of the large enterprises now use the new blast welding and punching techniques, new chemical processes, and automated control systems. A highly productive strain of wheat, high-standing-power Novosibirskaya-67, is spreading in the various regions of Western Siberia. The seismic regions of Siberia have been mapped, and the engineering and seismological evaluation of the Baikal-Amur Railway area has been produced. Substantial assistance has been given in prognosticating the development of the country's fuel and energy balance.

For all practical purposes, 40-50 per cent of the projects handled by the institutes of the USSR Academy of Sciences pertain to applied research, and the percentage is even higher at the academies of sciences of the Union republics and the sectoral academies. The USSR Academy of Sciences spends 75 per cent of its budget on scientific institutions, and 25 per cent on goal-oriented financing, while reserving 1 per cent for any unexpected problems that may arise.

Apart from the all-Union, state level, there is the sectoral level, ministerial and departmental level in the guidance of science. At this level, the necessary rate in the development of production and labour-productivity growth is being ensured on the basis of the achievements in science, technology and organisation; here, a coherent technical policy is elaborated and realised, scientific and technical novelties and advanced experience are introduced, the technico-economic indicators of production are raised; labour, production and management are organised on scientific lines for the best use of everyone's knowledge and experience. The ministries and departments make

regular evaluations of the scientific and economic level achieved in production, and map out ways for the most efficient use of scientific and technical accomplishments, directing the work of R & D organisations in their sector. In most instances, these organisations are subordinate to sectoral chief administrations, apart from organisations tackling tasks of ministry importance, which are subordinate to the ministries' technical administrations. Thus, the Technical Administration of the USSR Ministry of Gas Industry exercises direction of all the R & D organisations in its sector.

State plan assignments make up roughly 10-20 per cent of the assignments in the plans of R & D organisations of industrial ministries, ministry plan assignments, 20-30 per cent, work under contract with other organisations, 35-60 per cent, and work on the initiative of scientific personnel, up to 12 per cent. These organisations are quite free in choosing their contractual work. Broad initiative for researchers in framing plans is a distinctive feature of Soviet scientific activity. Thus, in 1972, the ministries and departments presented about 1,200 scientific and technical problems suggested by scientists, and 240 of these were written into the state plan.

In their guidance of R & D activity, the ministries and departments rely on their technical councils, on which leading specialists in a given field are represented to provide the expertise. In close contact with the State Committee for Science and Technology, the ministries and departments work to organise the scientific and technical propaganda and information service, which is usually combined with the technico-economic analysis and patent and licence service, and also to establish bilateral and multilateral ties with foreign countries.

Science Policy and Scientific Activity

The Soviet science management system has exerted an active influence on the rational structuring of the science institutions and centres network in the country, and the organisation within these of basic and applied R & D.

The numerous research, development and technological organisations are subordinate to the sectoral minis-

tries and departments, which have a special responsibility for the pace and level of scientific and technical progress and control the character of their research, the range of topics and the results.

Research centres have been set up at a number of major enterprises. Thus, the research centre at the Minsk Tractor Works has done much to make the Belarus tractors a great success. These tractors have been marketed abroad, notably in Latin America and the USA.

Ever more frequently, R & D establishments base their thematic plans on direct orders from enterprises. Thus, under an order from the Minsk Tractor Works, the Volgograd Research and Design Institute of Automated Control Systems in Tractor and Agricultural Engineering developed the first electronic quality control service.

In contrast to most Western countries, the Soviet Union has concentrated its basic theoretical research not mainly at the universities but at the institutes of the USSR Academy of Sciences, the academies of sciences of the Union republics and the sectoral academies. The institutions of higher learning have a more modest role to play than they do in the United States, Canada, Western Europe and Japan.

Over the past few decades, the number of Soviet science establishments multiplied by something like 2.5 times, from 2,359 in 1940 to 5,327 in 1975. There has been an especially marked growth in the number of research institutes, their branches and departments, the forms of science organisation advocated by Russia's leading minds even before the October Revolution. Their number more than trebled, from 786 to 2,805.[1] The number of institutes at the USSR Academy of Sciences went up from one in 1917 to 78 in 1940,[2] and continued to grow; many research institutes (especially in the technical sciences) were transferred from the Academy to the various departments. Still, at the end of 1975, the USSR Academy of Sciences had 246 science establishments, employing 41,836 scientific personnel (with part-time personnel), including 678 academicians, full-fledged members and corresponding members. Altogether, the USSR Acade-

[1] *The USSR in Figures in 1975*, p. 69.
[2] *Organisation of Scientific Activity*, p. 213.

my of Sciences, the academies of sciences of the Union republics and the sectoral academies had 869 science establishments with 108,000 scientific personnel. [1]

The growing number of their applications for inventions and the introduction of research projects is evidence of the improvement in the technico-economic indicators of sectoral industrial research; the economic effect from the applied R & D, confirmed by the enterprises, has also markedly increased. Thus, from 1971 to 1973, about 640 new ideas in the mechanisation, automation and production technique were introduced at enterprises subordinate to the Council of Ministers of the Georgian Republic. As a result, they installed 130 new mechanised and automated lines, effected the comprehensive mechanisation of more than 380 sections, shops and lines of production, and started to turn out more than 40 new products. In 1972 and 1973 alone, 35 major institutes in Georgia completed and applied in production about 600 projects, which yielded an economic effect of more than 200 million rubles. Steps are being taken to bring about a marked improvement in the planning and coordination of research and accelerating the use of its results.

At the same time, the Soviet press has subjected various shortcomings in sectoral science to serious criticism. This field employs over one-half of the country's scientific personnel, but, says the press, despite the existence of science-production and production associations, and research centres at the large plants and combines, enterprises in some industries account for only 0.4-0.5 per cent of the total number of scientists with degrees. [2]

The US economist Ben F. Sands has considered in detail the shortcomings and weak spots in the USSR's organisation of industrial research. In an article he says: "Certainly the USSR has the personnel, organisational

[1] *The Economy of the USSR in 1975*, p. 167 (in Russian).

[2] The scientific and technical lag of the industries turning out consumer goods is to some extent a reflection of the overall tendency for these industries to have a lower science-intensiveness as compared with the producer goods industries. Thus, in the US textile industry R & D funds come to something like one-thirtieth of those in the chemical and engineering industries, and to one-seventieth of those in the electrotechnical and electronic industries. Compared with the woodworking and furni-

ability and funds required to support a high-quality industrial R & D establishment. The problem has been, and will continue to be, the introduction of the results of the R & D to the market." He gives a warning against overrating this and other problems in the Soviet organisation of industrial R & D, while ignoring the unwarranted waste, inefficiency, duplication and resistance to innovation in the United States. He says: "The ability to purchase an almost infinite variety of options on large numbers of different models of what is basically the same automobile is hardly proof of the superiority of a capitalist system. It could be used by an objective observer as an example of the wasteful use of natural resources. Even the validity of the concept of the sovereignty of the consumer requires a value judgement that to the socialist is debatable." Sands draws the conclusion that the problem facing both the USA and the USSR, and all the other countries as well, is elaboration of systems which would help to identify and eliminate the existing obstacles in the way of scientific and technical progress. [1]

USSR ministries and departments exercise systematic control over scientific and technical progress in the sectors of the economy. Thus, the USSR Ministry of Power and Electrification, together with the State Committee for Inventions and Discoveries, has verified the state of the invention, patent and licencing effort at the sectoral institutes. It took a stringent approach in evaluating the R & D level, which in some cases fell short of modern requirements. This check-up provided an important stimulus in improving the work of all the scientific and technical divisions of the Ministry.

Meanwhile, legislative measures have been taken to induce the fullest use of the scientific and technical potential of discoveries and inventions not only when these are made but also in the future, as the conditions mature for their extensive introduction in the economy. In accordance with the Statute on Discoveries, Inventions and Rationalising Proposals, the authors of promising inven-

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ture industries, these funds come to less than one-half (*Research and Development in Industry 1969; Funds 1969; Scientists & Engineers*, January 1970; *Survey of Science Resources Series*, NSF 71-18, Washington, 1971, p. 53).

[1] *Research Management*, Vol. XVI, No. 3, May 1973, p. 36.

tions which are being used may be awarded prizes by ministries and departments recognising the advisability of using the inventions in the future at their enterprises, organisations and establishments, out of funds provided for by the Statute.

The system of measures mapped out by the Statute is designed to accelerate the movement of new scientific and technical ideas both along the vertical and the horizontal. The Statute says: "Rewards for the use of inventions shall be computed and paid out in accordance with the following procedure:

"1) for inventions used at one enterprise, organisation or establishment, by that enterprise, organisation or establishment;

"2) for inventions used at several enterprises, organisations and establishments of one and the same ministry or department, by that ministry or department;

"3) for inventions used by enterprises, organisations or establishments of more than one ministry or department, by the ministry or department in charge of the enterprise, organisation or establishment making first use of the invention, with subsequent compensation paid to that ministry or department of the corresponding amounts by the other ministries or departments whose enterprises, organisations and establishments have made use of the said invention. In the event of any dispute over which ministries or departments have the duty to pay the reward for the use of the invention, the question shall be decided by the State Committee of the USSR Council of Ministers for Inventions and Discoveries (§ 112)."

The Statute contains a special provision which says that any red-tape or other bureaucratic practices in the consideration and use of inventions and rationalising proposals, or deliberate infringement of the inventor's or rationaliser's right to receive a reward shall entail responsibility by the offending persons in office in accordance with the effective legislation (§ 8).[1]

Exceptional importance attaches to the development of direct links between sectoral and academic research,

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[1] See, *Statute on Discoveries, Inventions and Rationalising Proposals,* No. 584 of August 21, 1973.

and between fundamental science and production practice. Thus, a special chemical-energy engineering development bureau of the USSR Ministry of Chemical and Oil Machine-Building operates under the scientific guidance of the Institute of Thermophysics of the Siberian Branch of the USSR Academy of Sciences. On the basis of fundamental achievements and the mastery of "cold" plasma with a temperature of up to 50,000°C, a department has been set up to design and develop plasma generators for various chemical processes. Such generators, notably AC plasmotrons, help to accelerate chemical reactions hundreds and thousands of times, holding out promise of radical change in the technology of chemical production.

The Institute of Foundry Problems of the Ukrainian Academy of Sciences, together with the Leninskaya Kuznitsa Works, the Motorcycle, the Gorky Automated Machine-Tool and other plants, has carried out a comprehensive study of all the foundry shops in order to get a clearer idea of their technical level and possibilities for raising it. The collectives of the Institute and the enterprises then adopted joint commitments on the most rapid introduction of completed projects in production, and sealed them with agreements on cooperation. In 1972 and 1973, 30 research institutes in Kiev concluded something like 200 similar agreements with enterprises.

The "academic system" on whose lines Soviet science is organised does not, of course, belittle the growing role of educational institutions.

Education constitutes the real foundation for any policy in the field of science, for scientific activity, and for progress in science, technology and economics. Public education has always been one of Soviet power's chief concerns. The remarkable traditions in Russian pedagogy, going back to K. D. Ushinsky, were continued and multiplied after the October Revolution. Here, a tremendous role belonged to N. K. Krupskaya and A. S. Makarenko. In the very early years after the socialist revolution triumphed, the Soviet Union launched a policy designed to put education within reach of every citizen. The ultimate aim was to put in touch with the heights of modern knowledge the broadest possible circles of capable citizens who were willing to learn. In the early years of Soviet power, it carried out an unprecedentedly

massive drive to wipe out illiteracy in the country.[1] Russia's conversion into a land of total literacy enabled it successfully to effect first universal primary and then secondary education. The network of higher schools grew rapidly, with a radical change in the composition of the student body, where young people of working-class, peasant and working-intellectual origins began to prevail. The establishment of the state system of general and specialised education, including evening and correspondence courses, all up to a common state standard, had an invaluable role to play in advancing scientific activity (see Table V-1).

Table V-1

Population Standards in the USSR
(Beginning of year, mln persons)

	1939	1975	1976
Total number of persons with higher and secondary (complete and incomplete) education including:	15.9	117.0	121.5
complete higher	1.2	11.3	11.9
incomplete higher	14.7	2.8	2.9
specialised secondary		17.8	18.7
general secondary		32.0	34.4
incomplete secondary		53.1	53.6

Source: *The USSR in Figures in 1975*, p. 16.

The institutions of higher learning, the universities in the first place, are geared to the system of academic science establishments as a source of fundamental science. Let us note that in contrast to the United States and other countries, only higher schools offering 4-6-year courses are classified as such in the USSR. They enrol persons with a complete secondary education (10-11 years

[1] The percentage of those who could read and write between the ages of 9 and 49 years rose from 28.4 per cent in 1897 to 99.7 per cent in 1970 (*Public Education, Science and Culture in the USSR*, p. 21).

of secondary schooling, or the equivalent). The number of higher schools in the country went up from 817 in 1940/41 to 856 in 1975/76.[1] The higher schools now have 37 per cent of the USSR's scientific workers, including just under one-half of the doctors and over one-half of the candidates of science. The higher schools of the USSR Ministry of Higher and Specialised Secondary Education, apart from the higher schools of other departments, have 52 research institutes and design offices, more than 400 problem and 500 sectoral laboratories, 19 computing centres, 13 botanical gardens and 11 astronomical observatories. Basic research accounts for over one-third of all their research projects.[2] Vigorous steps are being taken to involve students, beginning with their first year, in research and experimental and development work. Here, everyone has heard of the experience gained at Novosibirsk State University, the Physico-Technical Institute, the Bauman Higher Technical College in Moscow, Moscow State University, Leningrad State University and other higher schools. The activity of student science societies has acquired considerable scope, and this has resulted not only in a growth of their membership but also in a growth of the scientific and practical importance of their projects.

In 1971 alone, Soviet higher schools spent more than 648 million rubles on R & D. To make fuller use of the research potential of the higher schools, especially in basic research, ever more extensive financing from the state budget of specific basic research projects is practised. In applied research, the higher schools have been ever more broadly involved in fulfilling long-term research projects under economic contract. As was said in Chapter Four, the higher schools are being integrated with sectoral research institutes, design bureaus and science-production associations in complex educational and science centres. Thus, scientists at the higher schools in the North Caucasus have helped the October Revolution Chemical Plant in Rostov to improve the production techniques, install an automated control system, and make its environmental protection more efficient. An educational and science-

[1] *The USSR in Figures in 1975.*
[2] *Vestnik Vysshei Shkoly* No. 1, 1970, p. 9.

production complex has been set up on the basis of the Taganrog Radio Engineering Institute, including a higher school, a research institute, a development bureau and an experimental enterprise. The effect obtained from its projects has fully covered the outlays on its organisation.

At the beginning of 1973, more than 200 student design bureaus were already working at higher schools in the USSR tackling both educational and production problems.[1] The USSR Academy of Sciences and the academies of sciences of several Union republics have decided to offer annual prizes for the best student projects.

Something like 50 million persons are enrolled at general education schools in the USSR, and serious attention is being given to the timely identification and fostering of young talent. Thus, the various departments of Moscow State University annually stage olympiads for senior schoolchildren, and have study groups whose members are as a rule the first to be enrolled at higher schools. One such study group has been operating successfully for many years at the Mechanico-Mathematical Department of the University. Leading scientists—academicians and corresponding members of the USSR Academy of Sciences and professors—devote much time and effort in working with the gifted teen-agers. Many leading scientists of the Academy's Siberian Branch are actively involved in the annual "summer schools" at Akademgorodok, for which invitations are issued to the winners of correspondence science olympiads from Siberian towns and villages. These are the young people who are enrolled at the boarding school set up by Novosibirsk State University.

Following a broad discussion in the Soviet press over the past few years a network of specialised secondary schools was set up to provide in-depth instruction in some subjects like physics, mathematics and foreign languages. In the 1970/71 academic year, the Soviet Union had 1,140 such schools, with an enrolment of over 393,000 boys and girls. While studying all the subjects included in the curricula of the mass general education schools, the pupils of these schools have special classes to give

[1] See, *Proceedings of an All-Union Conference on Methodological Questions in Planning and Prognosticating the Development of Higher Education in the USSR*, Moscow, 1973.

greater depth and breadth to their knowledge in their special subjects. Similar classes in some scientific and technical subjects are also available in the conventional general education schools, when the teachers are available.

Introduction of new school curricula in the second half of the 1960s for all the basic subjects, which had been worked out with the participation of leading specialists in their fields, did much to help improve the scientific grounding of schoolchildren. At the same time, new school textbooks were also produced. This important and responsible work was directed jointly by the USSR Academy of Sciences and the USSR Academy of Pedagogical Sciences, whose departments repeatedly discussed the draft curricula. Thus, the new biology curriculum provides for the study, on a molecular level, of intracellular processes, including the energy balance and metabolism, the basic uniformities governing the transmission of hereditary traits, the nature of genes and the genotype. This allows the study in secondary school, on the basis of modern scientific conceptions, of the regularities governing the development of organisms, the fundamentals of their vital activity and the evolution of organic matter from primitive forms to man. The study of the theoretical fundamentals of general biology is always tied in with the practice of agriculture and medicine. In the physics classes, pupils are acquainted with the fundamentals of molecular-kinetic and electron theories, and with elementary nuclear processes. In studying the laws of physics, they also receive information about the principles on which atomic power stations and heat engines operate, about the generation, transmission and use of electricity, about the means of communication, electrical engineering and radio engineering. The astronomy course tells them about the latest advances in the study of outer space, and so on.

The USSR Supreme Soviet has always kept public education within its field of vision. The Sixth Session of the Eighth USSR Supreme Soviet, which met in July 1973, approved the Fundamentals of Legislation of the USSR and the Union Republics on Public Education. The proposal to draft these had been put before the Presidium of the USSR Supreme Soviet by the Commission on Pub-

lic Education, Science and Culture of the Soviet of the Union of the Seventh USSR Supreme Soviet. The Presidium authorised the USSR Council of Ministers to draft the Fundamentals, and this was done by scientists, teachers, lawyers, prominent workers in education and representatives of many departments and organisations concerned. The draft was published in the press for discussion and consideration by the Commissions on Public Education, Science and Culture, the Commissions of Legislative Proposals, and the Commissions for the Affairs of Young People of the two Chambers. The published draft of the Fundamentals drew more than 3,000 proposals and remarks, and a joint preparatory commission of deputies was set up with the participation of the heads of Union Ministries of Public Education, Higher and Specialised Secondary Education, and Justice and the State Committee of the USSR Council of Ministers for Vocational Technical Education to consider these proposals. Following the adoption and introduction of various amendments and additions to the draft, it was submitted for approval to the USSR Supreme Soviet, at whose session 39 deputies voiced their considerations and remarks. After the debate, the Supreme Soviet enacted the draft into law.

The Commissions on Public Education, Science and Culture jointly considered with equal thoroughness the state of general secondary (evening and correspondence) education for working-class and rural young people, and produced a draft decree on the matter. At one of its sittings, the Commission of the Soviet of the Union considered the question of the state and improvement of the work of specialised secondary schools, something that was done after a close scrutiny of more than 200 technical colleges. Data from various sources were drawn for the drafting of recommendations.

The USSR is the first state which has consciously brought about a conjunction of science and organisation. This it has done at every stage of its development. The system of the agencies by means of which the state directs science has worked out and implemented in a balanced manner, with the broad support of scientists and

technical workers and all the other working people, a coherent system of organisation and direction of scientific activity. This system is an organic part of the metasystem of economic planning, constituting one of its ever more important and leading elements.

The new USSR Constitution (1977) lays down that "the jurisdiction of the Union of Soviet Socialist Republics, as represented by its highest bodies of state authority and administration, shall cover:

...pursuance of a uniform social and economic policy; direction of the country's economy; determination of the main lines of scientific and technological progress.... the drafting and approval of state plans for the economic and social development of the USSR, and endorsement of reports on their fulfilment..." (Article 73, para 5). Citizens of the USSR "are guaranteed freedom of scientific, technical, and artistic work. This freedom is ensured by broadening scientific research, encouraging invention and innovation, and developing literature and the arts. The state provides the necessary material conditions for this and support for voluntary societies and unions of workers....

The rights of authors, inventors and innovators are protected by the state." (Article 47).

Chapter Six

Expertise and Control

The growing scale and pace of scientific activity have markedly enhanced the importance of decisions in science policy, and state planning and coordination of R & D. With the growing level of scientific, technical and social development, any mistakes in the selection of the main scientific and technical lines and individual projects tend to cost much more, and not only or so much in terms of palpable financial losses, but—and this is much worse —in the not so easily renewable losses of time, enthusiasm and creative drive among researchers, inventors and innovators.

Accelerating Scientific and Technical Progress

The success of every grass-roots research collective largely depends on the right selection of topics and the focussing of attention and effort on solving the most important problems in science and technology. On September 24, 1968, the CPSU Central Committee and the USSR Council of Ministers enacted their Decree "On Measures for Enhancing the Efficiency of Scientific Organisations and Accelerating the Use of Science and Technology in the Economy". It said that low productivity at some low-key research institutes, work on casual and minor topics, and duplication have led to a dispersal of effort by specialists, extension of periods for fulfilling R & D projects, freezing of material values, and so on.

In 1975, of the 5.1 million proposals which came from inventors and rationalisers, 3.9 million were applied in production. [1]

[1] *The USSR in Figures in 1975*, p. 72.

In the sixth five-year period (1956-1960) the number of new types of machines, equipment, devices and instruments first developed in the USSR was three times the figure for the fifth five-year period (1951-1955), and this was almost doubled in the seventh five-year period (1961-1965). In the subsequent period, the figure fell slightly. This applies mainly to machinery, equipment and devices, but also to instruments, means of automation and computing machinery.

From 1966 to 1970, 4,300 new models of machines, devices and instruments were developed on average every year, from 1971 to 1975, 4,100.[1] This quantitative reduction is largely due to the much higher qualitative demands being made on new hardware. The growing potentialities for qualitative growth will also be seen from the number of inventions and new ideas realised, which have increased from year to year, and also the amounts of expected annual economies. Thus, in 1975, 319 million rubles went into inventions and rationalisations, as compared with 147 million rubles in 1965, while the economies increased, respectively, from 1,908 million to 4,805 million rubles.[2]

The time lag between the origination of a scientific and technical idea and its engineering is substantially reduced through the integration of science and production in the form of science-production complexes. The importance of the time factor in scientific and technical progress is emphasised by the very fact that, according to Soviet expert estimates, both the scientific information and the industrial products turned out tend to be totally renewed every 15-20 years.[3] Accordingly, the Statute on Discoveries, Inventions and Rationalising Proposals lays down strictly defined and fairly short-time frames for assessing scientific and technical innovations.

The preliminary expertise has to be carried out within 15 days of the receipt of the application for the issue of an author's certificate or patent by the State

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[1] *The Economy of the USSR in 1975*, p. 71.

[2] Ibid.

[3] Y. V. Kosov, G. K. Popov, *Administration of Intersectoral Scientific and Technical Programmes*, p. 19.

Committee of the USSR Council of Ministers for Inventions and Discoveries. [1]

State scientific and technical expertise of inventions has to be carried out within a period of not more than 6 months from the date of the filing of the application with the State Committee of the USSR Council of Ministers for Inventions and Discoveries. Within that period, the applicant must be informed of the decision to issue an author's certificate or patent, or a motivated refusal of such issue. [2]

The said period may be duly extended in the event of an inquiry from the applicant or the applicant's presentation of additional material, in accordance with §§ 54 and 55 of the Statute.

Where, in accordance with the present Statute, the period for considering the application is extended, and its consideration is suspended, the applicant must be duly notified of this. [3]

Any unwarranted delay in the examination period, as a rule, entails a considerable increase in the cost of the development and introduction of hardware and technology. Meanwhile, all over the world forecasts both of the duration and the cost of R & D tend to face considerable difficulties. A poll of R & D chiefs in five US industries showed that 30.1 per cent of those polled earned a "bad" and "very bad" rating for their preliminary evaluation of the length of the research period, while 21.9 per cent had the same ratings for the length of the development period; 16.5 per cent of the assessments of the value of research and 12 per cent of the value of development were blackballed. [4] In the Soviet Union, the computation of the economic effect of R & D at the time the technical assignment is formulated, is in effect provided for through the established ceiling evaluations by the GOST state standard—15.001—which is why it is mandatory and normative.

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[1] *Statute on Discoveries, Inventions and Rationalising Proposals*, § 47.

[2] Ibid., § 48.

[3] Ibid.

[4] R. E. Seiler, *Improving the Effectiveness of Research and Development*, p. 143.

The Problem of Selection and the Function of Expertise

Greater reliability of selection and adoption of scientific and technical decisions means a reduction of the probability of errors to a minimum. This task should be fulfilled by the system of state control of the scientific and technical level of new development projects, something that has to be carried out step by step. In this context, growing importance attaches to expert evaluations and control at every stage of R & D, from the scientific and technical expertise of inventions to control over the level of new development and engineering.

The institution of independent experts becomes especially important today both at the level of individual organisations and departments, and on the level of the state's scientific and technical policy, for independent extradepartmental expertise is alone capable of producing the right evaluation of various alternative decisions.

Consequently, the point is not to effect some specific improvement of the established methods, but to set up an integrated system of extradepartmental expertise with a subsystem of state control over the scientific and technical level of development.

This country has a wealth of experience in this field, which is rooted in the 19th and even the 18th century. [1] However, most important today is the experience in scientific activity since the October Revolution, which was reflected in Lenin's articles about the Workers' and Peasants' Inspection. According to Lenin, the scientific substantiation and scientific expertise of any organisational and administrative decisions must be guaranteed by an adequate diversity of expert institutions and—and

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[1] It was Peter the Great who suggested that the Academy of Sciences of Russia had the task not only to develop science and maintain national scientific prestige abroad, but also to train scientific personnel and to provide scientific consultations for government establishments. He said: "Governing officials in collegia, chancellories, offices and other official places must resort, in every case bearing on the sciences, to the Academy and to demand its advice." (Y. Shtelin, *Curious and Memorable Stories About the Emperor Peter the Great,* in Russian.)

this is most important—their adequate scientific level.[1] That was the basis on which, in accordance with Lenin's directive, work was carried on in elaborating the GOELRO plan which was the prototype of long-term prognostication and planning of scientific and technical progress. Various establishments and individuals, who were paid by the job, were involved on an extradepartmental basis in working out and implementing the GOELRO plan (a special 20-million ruble credit was set aside for the purpose). Various expert groups and organisations played an important role in the activity of the People's Commissariat for Public Education, the Chief Science Administration, the Science and Technology Department of the Supreme Economic Council, and in establishing and developing the early Soviet research institutions, commissions and associations for dealing with various problems.[2] In the past few years, both negative and positive experience has been gained in extradepartmental expertise on inventions and certification of the quality of new products. Thus, a specific approach to the certification of new product quality has been worked out in power engineering.

However, on the whole, the individual elements of expertise on inventions and product-quality certification do not yet make up a single mechanism, and the task is to create an effective system of state control of the scientific and technical level of new projects.

The place and role of scientific and technical expertise in raising product quality is considered by the President of the European Organisation for Quality Control, J. van Ettinger, and J. Sittig, one of the founders of the Statistics Society of the Netherlands. They say that experts in scientific research have the duty to collect and

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[1] See, V. I. Lenin, "Better Fewer, But Better", *Collected Works*, Vol. 33, pp. 491-92.

[2] See, M. S. Bastrakova, *The Formation of the Soviet System of Science Organisation*. Thus, when putting forward the project for a hydrological institute, Professor A. M. Glushkov emphasised its expert functions which were ensured by its being a part of the Academy of Sciences system "for the purposes of scientific authority, extradepartmental objectivity and systematic character of research" (*The Organisation of Science in the Early Years of Soviet Power*, p. 158).

analyse data and to compute the optimal variant for any possible approaches. But it is a prerogative of the chief to decide on the tasks of organisation and to adopt the final decision. Relying on his intuition and experience, he alone is capable of comparing the imponderable advantages and disadvantages of any decision with the additional outlays or expected economies. Scientific expertise to back up any decision has the advantage of releasing the head of the firm from some duties which may be performed by more qualified specialists, leaving him more time to decide on matters of strategy. Consequently, the spreading use of the methods of scientific expertise does not at all mean that the heads of companies taking decisions on the basis of experience and intuition have been hopelessly outdated and must give way to specialists in operations research. The intuition of leaders and scientific methods of expertise should not compete but complement each other. [1]

As of October 1972, there were nearly 3,200 committees and experts in the United States. [2] Experience shows that their recommendations and, consequently, the decisions taken on the basis of these, do not always stem from the objective and unbiased approach. [3]

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[1] J. van Ettinger, J. Sittig, *More ... Through Quality.* This approach is similar to the following rule formulated for leaders by Francis Bacon in the 17th century, when he wrote: "How kings are to make use of their council of state: that, first, they ought to refer matters unto them, which is the first begetting or impregnation, but when they are elaborated, moulded and shaped in the womb of their council, and grow ripe and ready to be brought forth, that then they suffer not their council to go through with the resolution and direction, as if it depended on them, but take the matter back into their own hands, and make it appear to the world, that the decrees and final directions ... proceeded from themselves [the leaders—*Y. Sh.*], and not only from their authority, but, the more to add reputation to themselves, from their head and device" (*The Works of Francis Bacon,* Vol. II, London, 1826, pp. 291-92).

[2] In Washington alone there were an estimated 2,400 such committees, of which 1,500 were set up to provide advice to government agencies specifically in areas of science and technology (Kendrick Frazier, "Science Advisory Committees". In: *Science News,* Vol. 102, No. 1, 1972, p. 3).

[3] The well-known US scientist Leo Szilard wrote in a story titled "The Mark Gable Foundation": "You could set up a foundation, with an annual endowment of thirty million dollars.

In July 1972, a special group headed by the President of the National Academy of Sciences published a report entitled "The Science Committee", which said that such groups sometimes are formed merely to ratify or support an already made decision or policy. By striving for consensus, committees often produce reports that are bland, wishy-washy, platitudinous and useless. Experts who tend to stand up for their views on controversial issues are not as a rule included in such committees. Many reports are purely technical, ignoring the socio-economic aspects of the problem.

The group suggested that committees include experts with differing views, with a quantitative balance between them. In the absence of a consensus on the final report, the minority opinion should also be presented. It was also suggested that the committees include more young members (35 years and under), more women and more members of ethnic minorities in order to increase the diversity of approaches and standpoints.[1] The committees should be renewed at least once in three years, and the snowballing method should be used in extending the range of candidates: each initially invited expert is requested to recommend several new experts, and this is repeated two or three times.

Research workers in need of funds could apply for grants, if they could make out a convincing case. Have ten committees, each composed of twelve scientists, appointed to pass on these applications. Take the most active scientists out of the laboratory and make them members of these committees. And the very best men in the field should be appointed as chairmen at salaries of fifty thousand dollars each. Also have about twenty prizes of one hundred thousand dollars each for the best scientific papers of the year ... the best scientists would be removed from their laboratories and kept busy on committees passing on applications for funds ... the scientific workers in need of funds would concentrate on problems which were considered promising and were pretty certain to lead to publishable results. For a few years there might be a great increase in scientific output; but by going after the obvious, pretty soon science would dry out. Science would become something like a parlor game" (Leo Szilard, *The Voice of the Dolphins and Other Stories,* New York, 1961, pp. 100-01).

[1] Kendrick Frazier, "Science Advisory Committees". In: *Science News,* Vol. 102, No. 1, 1972, p. 3. There were growing demands for a different approach to the NAS expert service following press criticism of various errors its experts had made.

At the end of 1972, the US Congress enacted a law which put the duty on the Legislature and the Executive constantly to scrutinise the activity of advisory committees and to decide whether they should be dissolved, merged or reorganised. The membership of these committees should be so regulated as to balance out the various approaches and functions. The meetings of the committees should be open to the public, with the exception of some closed sessions, but even then the President or the head of the department concerned must explain why secrecy is necessary. The new Act is designed to prevent the establishment of superfluous advisory committees and the dissolution of the truly useful ones. [1]

However, the reorganisation of the US science policy mechanism which soon followed upon the passage of the Act revealed a tendency towards a reduction in rather than an enhancement of the role of scientific and technical expertise. Apprehension of the growing political influence of scientific advisors prevailed over the urge to make independent expertise truly effective.

The "experts cult" which has taken shape in the United States and other Western countries, especially following the "sputnik panic" in the late 1950s, and the attitude to that "cult" on the part of their ruling circles deserve serious attention.

US writers note that four major risks are involved in project selection, because:

1) the selected project may be unsuccessful;
2) if successful, [2] the results may be unprofitable;

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[1] *Science, Engineering, Technical Manpower Comments,* October 1972. A statement issued by the Federation of American Scientists (FAS) said: "We view with dismay and alarm this further decline in the role of scientists in Government.... As the issues of national science policy become more complicated, the voice of science becomes more necessary. We believe that disinterested expertise should be sought rather than suppressed. The policies being followed by the Administration, in downgrading science, are leaving the scientific community with an ever greater feeling of frustration." (*Science News,* Vol. 103, No. 5, February 3, 1973, p. 70.)

[2] "One of the more concise definitions of technical success is 'defining a performance space and attainment of a point in that space with the expenditure of not more than *X* dollars and *T* time units'" (R. E. Seiler, *Improving the Effectiveness of Research and Development,* p. 140).

3) a rejected project might have been successful and profitable;

4) if successful, the results may be beyond the company's scope of operations. [1]

Quite obviously, the elements of risk stated in points 2), 3) and especially 4) bear the mark of capitalist conditions, which set the limits to scientific activity.

This also applies to most of the factors which determine the evaluation of proposed projects in private corporations, and are grouped as follows:

Technical factors

Research direction and balance

Timing of research

Stability (prominence of the market)

Position factor

Growth factors

Marketability factor (market potential, competitive environment)

Production factors

Financial factors (expected rate of return on invested capital)

Protection (possibility of a patent). [2]

Every project should strike a balance between being so small that a clearly defined unit of research endeavour is not included, and so broad and all-inclusive that the relevant data cannot be accumulated and compared in a meaningful fashion. [3] Among the key factors in project selection are the probability of technical success, timing and balance. Financial factors receive the greatest amount of attention, since success in any business venture can be measured in terms of profits. [4]

The prospects for marketing new products are of crucial importance in a market economy. Every year, an average of 80 per cent of new products in the United States cannot be marketed and their production is discontinued. Thus, in 1970, about 30,000 new products appeared on the US market, of which 24,000 disappeared within the year. One US marketing specialist believes that the main

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[1] R. E. Seiler, op. cit., p. 129.
[2] Ibid., pp. 137-38.
[3] Ibid., pp. 145-46.
[4] Ibid., pp. 143-44.

reasons are mistakes in testing and introduction of new products. [1]

In Britain, the direction of industrial research is based on the following criteria:

the extent to which they help to realise the company's overall policy;

the extent to which they bring about optimal loading of production capacities in capital-intensive industries;

the extent to which they meet the demands of profitability in the other industries;

the extent to which they help to make the fullest and most efficient use of the company's available resources. [2]

Large-scale socialist production today has established its own criteria, making ever greater demands on optimisation of management decisions and so also on their expert evaluation and substantiation.

Scientific and technical expertise has an especially important and responsible role to play in evaluating the results of the work of R & D establishments and project selection. Soviet writers have noted the need to raise the standards for project quality, on the basis of a clear-cut system of expertise within design organisations and the industry, so as to make all scientific and technical decisions first class. They recommend that the best scientists and the most competent institutions should be invited to make evaluations, and that interdepartmental expertise should be used for the projects of especially important and complicated structures.

This kind of approach has yielded a tangible effect. Thus, in 1973, expertise provided by the State Building Committee of the USSR Council of Ministers established the possibility of cutting the estimated cost of construction under finished projects by roughly 1,700 million rubles, or 3.8 per cent, with a simultaneous improvement in some projects of capacity and labour-productivity indicators in order to bring out fresh potentialities for increasing the output through the technical re-equipment

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[1] Philip Gisser, *Launching the New Industrial Product*, New York, 1972.

[2] T. S. McLeod, *Management of Research, Development and Design in Industry*, London, 1969.

of production. The need was noted to pool the efforts of design organisations, enterprises and research institutes.

The USSR now has a sufficiently ramified state mechanism for expertise and control of R & D projects. It is represented by some functions of the organs of legislative power (standing commissions of the Chambers of the USSR Supreme Soviet), the judiciary (the Supreme Court, the Procurator's Office of the USSR), and most importantly, the agencies of the executive power. The USSR State Planning Committee, the State Committee of the USSR Council of Ministers for Science and Technology, the State Committee of the USSR Council of Ministers for Inventions and Discoveries, the Standards Committee, the Ministry of Finance and the sectoral ministries and departments are subordinate to the USSR Council of Ministers. The USSR Academy of Sciences is also subordinate to the USSR Council of Ministers, while the sectoral academies—the Academy of Agricultural Sciences, the Academy of Medical Sciences, the Academy of Pedagogical Sciences, and the Academy of Construction and Architecture—are subordinate to the corresponding ministries and departments. Expert functions in the field of social research are exercised by the Academy of Social Sciences and the Institute of Marxism-Leninism under the CPSU Central Committee. These are supplemented with mass organisations, including Party branches, Young Communist League organisations and the trade unions. The functions of scientific and technical expertise and control are systematically exercised by the State Committee of the USSR Council of Ministers for Inventions and Discoveries, its Expert Council, the All-Union Research Institute for State Project Expertise, and the Central Research Institute of Patent Information, and also science societies, and the All-Union Society of Inventors and Rationalisers. The USSR Standards Committee has a broad spectrum of expert functions in controlling product quality.

The State Committee for Science and Technology examines and takes decisions on controversial issues arising between ministries and departments on the realisation of intersectoral programmes. It sets up science councils in the key intersectoral scientific and technical problems, scientific and technical commissions and expert groups,

and recruits specialists to work on these. The departments, bureaus and machinery of the State Committee for Science and Technology and its science departments with their sections are supplemented with the Scientific and Technical Complex of the State Committee of the USSR Council of Ministers for Science and Technology. Hardly any head ministry can expect to recruit such a quantity of highly skilled specialists from various fields of science and set up science councils for the programmes assigned to it. In some industries, the functions of expertise and control are vested in the technical councils of ministries and departments and the scientific institutions and individual groups of experts which they recruit; the machinery of the Ministry of Finance has an especially active role to play in exercising financial control over R & D projects.

The State Committee of the USSR Council of Ministers for Inventions and Discoveries has, according to the Statute, important functions of scientific and technical expertise and control. Here, it works together with the State Committee of the USSR Council of Ministers for Science and Technology, with the Standards Committee, the USSR Academy of Sciences, the State Planning Committee and other agencies.

Thus, in order to provide expertise for applications involving especially complicated discoveries and inventions, the State Committee of the USSR Council of Ministers for Inventions and Discoveries and the ministries and departments, determined in accordance with § 79 of the relevant Statute, have the right to recruit the necessary specialists from other ministries and departments. The heads of ministries and departments have the duty to make available such specialists in these cases. [1]

Of tremendous importance for the correct and rapid settlement of controversial issues which abound in new discoveries and inventions is the arrangement of cooperation between the expert agencies of the Committee—Control Council for Scientific and Technical Expertise and other agencies. According to the Statute, such matters are considered by the Control Council for Scientific

[1] *Statute on Discoveries, Inventions and Rationalising Proposals*, § 80.

and Technical Expertise of the State Committee of the USSR Council of Ministers for Inventions and Discoveries. The Chairman of the Committee or his deputy may also refer to the Control Council other matters arising from expertise on invention applications.

The cases referred to the Control Council for Scientific and Technical Expertise are considered collegially by at least three of its members, and the procedures governing consideration of cases by the Council are laid down by its Statute.

The decisions of the Control Council are final and are not subject to appeal. The Council may reconsider its decision in the event of a protest by the Chairman of the State Committee of the USSR Council of Ministers for Inventions and Discoveries made on the grounds of its decision being incompatible with the legislation in force or in view of new circumstances which have come to light. [1]

At the same time, mass organisations controlling the activity of state organs have a growing role to play in deciding on what happens to new scientific and technical ideas.

The whole effort in developing massive inventions and rationalising proposals is being carried on with the broad participation of the All-Union Society of Inventors and Rationalisers, trade unions and other mass organisations.

The All-Union Society of Inventors and Rationalisers exercises social control over the observance of legislation in the sphere of inventions and rationalising proposals. It has the duty to give inventors and rationalisers every possible assistance in their activity and in the protection of their rights, and also to promote the development and use of inventions and rationalising proposals in the economy. [2]

Under the socialist system, the mechanism of scientific and technical expertise and control is in principle based on a coherent conception of an expertise and control service (although now and again the lack of coordination caused by departmental and administrative bar-

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[1] *Statute on Discoveries, Inventions and Rationalising Proposals*, § 148.

[2] Ibid., § 86.

riers does have an effect on the work of some of its units). The findings and recommendations of experts are realised on the basis of feedback, by means of which operational control is ensured. In other words, the expertise and control service is a *system.*

The functions of scientific expertise are exercised mainly by the science councils set up under the Presidium of the USSR Academy of Sciences and the State Committee for Science and Technology to deal with individual problems, by technical councils at ministries and departments, and also by various coordination sectoral, complex, regional and other councils. Here again, the period within which their expert evaluation has to be handed down is strictly limited. According to the Statute, an application for the issue of a diploma for an invention that has been accepted for consideration, is referred, depending on the nature of the proposed discovery, to the USSR Academy of Sciences, the academies of sciences of the Union republics, the sectoral academies, universities, leading research organisations or educational establishments of ministries and departments. Within three months, these organisations must present their finding to the State Committee of the USSR Council of Ministers for Inventions and Discoveries concerning the existence of a discovery (setting forth the recommended discovery formula), together with an evaluation of its significance and recommendations on the ways of its possible use. In the event of a negative finding, the motives for it must be stated. Whenever necessary, the State Committee of the USSR Council of Ministers for Inventions and Discoveries may invite the author of the discovery to participate in the consideration of his application. [1]

Science councils, as organs of scientific expertise, do not cover the whole network of the country's research establishments, for there remain outside their field of vision many interinstitutional (interhigher school, etc.) research and technical projects. Some members of these councils are scientists who are acknowledged authorities in their field and men of major scientific repute, but

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[1] Ibid., § 16.

they lack the time and frequently the opportunity to participate in the day-to-day work of these councils. Accordingly, the brunt of the effort falls on the rank-and-file members, exercising the main expert functions.

Some councils have their own funds and so are able to invite scientists or groups of scientists to provide extradepartmental expertise on a contractual basis. This helps to make their activity much more valuable and important, to avoid considerable loss of resources and time in consequence of erroneous decisions, which are, as a rule, very much higher than the costs of making the work of science councils more efficient.

Further improvement of the Soviet expertise and control service is closely connected with the installation of an automated system for control of scientific and technical progress. Of course, no automated system can of itself produce optimal selections of R & D projects deserving greater concentration of effort than the rest. What is more, the better the information service, the larger the range of alternatives, and the greater the difficulty in decision-making. Ultimately, it is man himself who has to take the decisions, with the help of electronic computers, his scientific knowledge and intuition. But "two heads are better than one" is a saying which is perhaps most relevant to this field. After all, intuition is subjective, and the opinions of individual experts should supplement each other, being averaged out in a common expert evaluation. However, objectivity, independence of expertise and freedom from departmental or any other pressure is a necessary condition for reliability of such expert evaluations.

Expertise-Control Service: Problems and Prospects

The system of independent extradepartmental scientific and technical expertise and state control of project standards has an important part to play in the whole effort to accelerate scientific and technical progress. Increasingly it will have to select the best projects and the most reliable performers, to choose necessary organisational structures and management procedures, and so on.

This system should be:

extradepartmental;
independent and scientifically objective;
efficient (on the basis of feedback);
operational; and
reliable.

Only a mechanism which has the necessary redundancy can meet these principles. Accordingly, the expertise-control service should consist of two basic components: *expert councils* and *scientific and technical firms.*

When I say expert councils, I mean above all a new basis for the work of *science-problem councils*, which it is advisable to convert into staffed and based on *khozraschyot* [1] principle organisations, so that only those who have the necessary qualifications, the time and the urge to work as experts should be on their staff. These men and women should bear moral and material responsibility for their work, that is, the time that they spend as experts should only be paid for their actual and not merely nominal participation in the work of the councils. [2]

It is also necessary to set up special funds to enable the reorganised science councils to use these at their discretion, for instance, to recruit individual experts or whole groups of scientists for independent extradepartmental expertise. All such funds could come from a state fund for the development of science and technology under the State Committee for Science and Technology. This would evidently not only make the work of the councils more vigorous but would also help sharply to enhance its quality, for the councils would be enabled to take

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[1] *Khozraschyot*—a method of planned economic management of socialist enterprises based on economic autonomy and commodity-money relations, implies balancing of costs and incomes, compensation for outlays out of current incomes, profitability, material incentives, and responsibility of the enterprise and its personnel.—*Ed.*

[2] Back in 1918, a minute on "The Organisation (Structure) of the Agricultural Department" proposed the establishment of a Council of Specialists as the science-consultation and science-organisation centre of the department. The basic form of its day-to-day work was to have been a "system of projects and topics" with mobile groups of researchers instead of a "fixed staff" of specialists. See, M. S. Bastrakova, *The Formation of the Soviet System of Science Organisation* (in Russian).

decisions more independently and objectively on various matters and to submit more solidly grounded recommendations for the directive agencies. Expertise for large projects, notably those which are of an intersectoral character, could be provided by the reorganised science-problem councils of the USSR Academy of Sciences, the State Committee for Science and Technology, the State Committee of the USSR Council of Ministers for Inventions and Discoveries, the Standards Committee, and interdepartmental scientific and technical councils, which must bear full responsibility for their recommendations.

The principles on which the science-problem councils could be reorganised into expert councils may include:

1. Framing of a Statute on the rights and duties of expert councils.

2. Establishment, under the Statute, of a "working nucleus" of expert councils consisting of payroll (at full or half salary) members and a small ancillary staff. [1]

3. Investment of the councils under the Statute with the powers of a juridical person.

4. Allotment of funds for the Council to use at its discretion for the needs of operational recruitment of external experts (for instance, on the basis of labour contracts).

Alongside the science councils, reorganised on *khozraschyot* basis, the task of intensifying scientific and technical progress will also be promoted by specially established *firms of scientific and technical consultants* directing the efforts of groups of highly qualified experts. The scientific and technical consultations provided by expert firms, which have to pay their way, could have a useful role to play in the provision of extradepartmental expertise. The work of the expert councils could be supplemented (and in some cases also controlled and duplicated) by the services of the scientific and technical firms, so as to make the expertise-control mechanism more reliable. But the important thing is to have these firms operate independently of departmental interests. They could conclude contracts with ministries, departments, science-

[1] Such a staff, including a technical secretariat, a typist pool, a copying service, etc., could cater simultaneously for several kindred expert councils.

production complexes, enterprises, research institutes and design offices for the provision of consultations in the selection of the most promising ideas and projects, and to promote their implementation.

A system of state control over the scientific and technical standards of projects is quite feasible in practice. It should supplement the existing elements of expertise for inventions and certification of product quality, while helping to transform these elements with an eye to the prospects of scientific and technical progress over the next few decades.

Depending on the place of a product along the way to the finished product, all manufactures could be classified under the following heads:

1. natural raw materials (oil, coal, iron ore...);
2. industrial raw materials (bricks, sheet steel...);
3. finished manufactured products (cars, clothing...);
4. "superproducts" (airline, hospital, city...).

The basic stages of production could be classified as follows:

a) technical assignment;
b) development;
c) production;
d) finished product.

For each class of products and for each stage in the development of the product, control could be either hard or soft, or could be waived altogether. [1]

What is of most concern for us here is the stage of technical assignment and development for classes of products like industrial raw materials, finished manufactured products, and "superproducts". Table VI-2 shows that at the stage of technical assignment control tends to grow from zero to soft for industrial raw materials and finished manufactured products, and onto hard control for the "superproduct". At the stage of development, soft control for industrial raw materials gives way to hard control for finished manufactured products; for "superproducts" at the same stage control once again becomes soft. Thus, for finished manufactured products control should be at peak at the second stage—development, and for the "superproducts" as early as the first stage, in the tech-

[1] J. van Ettinger, J. Sittig, *More ... Through Quality*, p. 73.

nical assignment. (As for industrial raw materials, the need for hard control tends to arise here only at the stage of production.)

The system of state control over scientific and technical standards for new projects could be so structured as to ensure hard control over the development of finished manufactured products and over technical assignments for "superproducts". The prospects for scientific and technical progress over the new few decades are such that the share of the most complexified types of finished manufactured products and of "superproducts" in particular will steadily grow within social production. There should be a parallel growth in the hardness of control at ever earlier stages of production as the manufactured product is complexified. Hard control over the formulation of the technical assignment for new types of "superproducts" and for the development of new lines of finished manufactured products would help to eliminate waste at the subsequent stages of production and issue of the finished product, and this, for its part, would help to relax control over these stages.

Hardness of control, I believe, could be substantially enhanced through the systemic use of independent expert evaluations, first, at the stage of project selection, and second, at the stage of project realisation. Graphic methods in evaluating projects and progress reports hold out important potentialities for doing this.

The use of these methods requires above all the invitation of several (at least two) independent expert groups. One of these, for instance, could be made up on the recommendation of the expert council concerned, and the other, of the scientific and technical firm. The experts in each group (5-7 persons) grade, in accordance with a five-point scale, each of the key technical, economic, production and commercial factors of the project. These marks are averaged out in the final evaluation, which decides the final selection of the project.

Independent extradepartmental expertise is a mechanism which helps to optimise not only project selection and development planning but also control of their implementation. It is designed to ensure above all optimal conditions for the development and realisation of the most fertile ideas.

Table VI-1

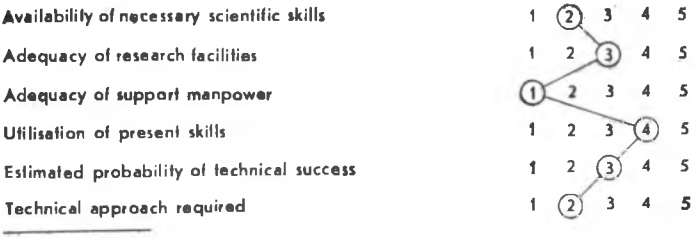
Use of Graphs in Project Reviews

Technical factors 1 2 3 4 5
Research balance 1 2 3 4 5
Timing 1 2 3 4 5
Stability 1 2 3 4 5
Position 1 2 3 4 5
Growth 1 2 3 4 5
Marketability 1 2 3 4 5
Production 1 2 3 4 5
Financial factors 1 2 3 4 5
Projection 1 2 3 4 5

Source: R. E. Seiler, *Improving the Effectiveness of Research and Development*, pp. 154-55.

Table VI-2

Specimen Graph for Evaluating Technical Factors of Projects


Availability of necessary scientific skills 1 2 3 4 5
Adequacy of research facilities 1 2 3 4 5
Adequacy of support manpower 1 2 3 4 5
Utilisation of present skills 1 2 3 4 5
Estimated probability of technical success 1 2 3 4 5
Technical approach required 1 2 3 4 5

Source: R. E. Seiler, op. cit., p. 154.

This requirement may be realised with the participation of a firm of scientific and technical consultants, whose experts are invited to provide qualified assistance to the management in securing clear-cut organisation of R & D project fulfilment and unflagging control over the whole process on the principle of sanctioning feedback.

The experience available in the world shows that the whole applied R & D process should be divided into four stages: origination of the idea, its evaluation, realisation of the project, and development, until the starting of production. At the first stage, the researchers themselves naturally provide the prime source of the new research ideas. They are followed by the marketing personnel and the consumers, whose growing and changing demand provides an impetus for new research projects. Finally, some of the ideas may come from the customers in production cooperation or from the management of the given enterprise or establishment. An idea from this or that source, or from several sources simultaneously, is studied from the standpoint of whether all the necessary and adequate information for its realisation is available. Only if it is, does the operation move into the next stage. In this way, the iterative control mechanism, operating on the principle of sanctioning feedback, is set in motion at the very beginning of the project.

At the second stage, when the idea is evaluated, this mechanism functions most vigorously, for that is where it has to sift the most promising ideas and to prevent any waste of resources on ideas which have no chances of success, however tantalising they may appear to be (it goes without saying that this approach is less applicable to basic research). In effect, the whole of the second stage consists of steps in control. The new research idea is evaluated, first, from the standpoint of its compatibility with the purposes and long-term plans of the enterprise (institute); second, its technical feasibility; third, its profitability; and fourth, from the standpoint of whether or not its realisation will upset the existing research programme. The idea is rejected if the evaluation is negative at any of these points. Only if the evaluation is positive at every point is the idea included among the research projects. The third stage, the stage

at which the project is realised, does not start until the sanctioning feedback confirms the availability of resources required for work on the new project.

At the third stage, following the preparation of drawings and blueprints, a time chart for work on the project is drawn up. The preparatory work, all the necessary research and the testing of its results are carried out in accordance with the chart. At this point, the control mechanism comes on stream once again. It is first established how successfully work on the project has moved from the standpoint of its readiness for development. In the event of a negative evaluation, the general state of work on the project is reviewed, and in the event of unsatisfactory results, the question of winding up the project is considered. If the general state of progress is found to be satisfactory, the project is returned to the previous phase of research and testing. Only if the first step in control yields a positive evaluation is the project included among the products and processes up for development. From there it moves to the fourth and final stage, but once again only after the control mechanism has established the availability of resources necessary for development and production.

Characteristically, the fourth stage begins with a study of the prospects for the use of the new product or process. Only on the strength of such a study does the project move into the phase of technological development, and prototype engineering and testing, engineering honing and, finally, start of production. No special control procedures are provided at this point because it is taken for granted that control at the earlier stages had been sufficiently reliable. Any possible minor flaws are eliminated in the course of the work.

But for that reason there is a growing role here (and partly also at the third stage) of financial control and economic instruments, which is due to the sharp increase in outlays when the project moves into the development stage. These instruments are designed to ensure uninterrupted transition from one stage to the next in realising the research idea (invention).

There is a need to work out methods for the selection of experts, making critical use of the existing criteria concerning reliability, precision of evaluation and non-

trivial approach to problems.[1] Accordingly, it is possible to organise more purposefully the training of scientific and technical experts at different levels, from the laboratory to the government department. This will be promoted by the establishment of courses in the principles of science policy for universities and schools of executives.

An efficient expertise and control service relies on real socio-psychological premises, and this is also borne out by some of the results in our poll, "How Do You Feel Working?"[2]

In the past few years, concrete projects for methods to be used in expert evaluations have appeared in Soviet writings. The USSR has made some advances in the scientific and technical expertise and control of manufactured product quality, especially in precision instrument-making. The experience gained here is also being applied to expertise and control both at preceding stages of production and at its now culminating stage of "superproducts".

The training of specialists for expertise and control at economic cybernetics, scientific organisation of production, psychology and other higher school departments was started not long ago. In order to prevent the very

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[1] Experts are classified as universalists and specialists who supplement each other. In order to enhance the effect obtained, it is recommended to set up groups of experts which are symmetrical and asymmetrical. In the first instance, the experts of both categories consider the same problem together and produce recommendations for its solution. In the latter, the universalists are invited to analyse some aspects of the problem, and the specialists, others. At the Battelle Memorial Institute, Thomas and McRory have also elaborated a method of synthesising the opinions of experts and analysing its sensitivity to deviations from the general opinion among the individual experts.

[2] Of those polled in the technical sciences, 36 per cent emphasised an incentive like the opinion of one's colleagues, which is evaluated on the same level as material incentives (40.8 per cent) and is rated five times as high as the opinion of one's immediate superiors or intimates, and 2.5 times higher than broad public recognition. On the whole, 34-39 per cent of those working in all the scientific fields designated the opinion of one's colleagues as the most important incentive for work, and 61-69 per cent, the share of publications recognised by specialists, as the criterion of creative productivity.

Table VI-3

R & D Project-Appraisal Work Sheet

	Project No. Title

Technical	1. Probability of Success: (Remarks)
	Low — well worked field or speculative idea
	Moderate — average prospects for technical success
	High — success highly probable
	2. Projected R & D cost:
	$ costs incurred to date
	$ total future projected costs
	$ recurring annual costs for protection if successful
	3. Time:
	Long range: more than three years
	Intermediate: one to three years
	Short range: one year or less
	4. Other technical factors

Economic	1. Estimated annual revenues
	$ per year revenues
	2. Estimated manufacturing capital investment
	$ total investment
	3. Estimated cash payout (capital investment and R & D cost divided by estimated revenues)
	More than three years
	One to three years
	Less than three years
	4. Other economic factors

Manufacturing	1. Effect on operations (Remarks) Will cause complex operating problems Desirable modification of new operation Highly desirable adjunct to present operations 2. Other economic factors
	Probability of successful commercial development [1 2 3] Low [4 5 6 7] Intermediate [8 9 10] High Overall appraisal of this proposal [1 2] Not justified [3 4] Marginal [5 6] Average [7 8] Above average [9 10] Outstanding Signature of appraisor Title Date

Source: R. E. Seiler, op. cit., p. 153.

few personnel from being scattered among the organisations and establishments, where their separate efforts would yield no appreciable effect anyway, it is advisable to concentrate them at expert councils and in scientific and technical firms, which are truly capable of exerting an influence on the solution of the key scientific and technical problems.

It is now possible, on a larger scale than ever before, to use the latest methods in organising and directing R & D like the evolutionary planning of experiments, systemic analysis and systems machine methods, and grid planning and management. The development of these methods with the use of displays, interfaces, and latest generation computers will help to create the necessary premises for automated control systems for scientific and technical progress in the future. This, for its part, will help to bring out and realise the still latent reserves in the use of scientific personnel, ancillary personnel, and experimental installations, facilities, etc.

The time is overdue for working out methods to obtain authentic expert evaluations. These are, in the order of growing authenticity:

1. The writing of scenarios.
2. "Brain-storming" and "ideas conferences".[1]
3. Strategic games.
4. Delphy.

It is advisable especially to work out reliable methods for long-term scientific and technical prognostication and planning with the use of independent expertise. "From the metasystem to the system" could be the guiding motto in this effort.

Once the overall long-term goals are brought out and their hierarchy established, there should follow a further structuring of the "goals tree" at the third, fourth and other tiers, right up to the technical assignment level.

The development of an expertise and control service would help substantially to raise the level of guidance

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[1] Werner Gilde and Claus-Dieter Starke of the GDR recommend, in their meaningful book *Idean muss man haben*, that in place of "brain-storming" there should be "ideas conferences", which are much more balanced.

of scientific and technical progress. Lenin said that every leader must "possess a high degree of personal appeal and sufficiently solid scientific and technical knowledge to be able to check people's work".[1] A functioning state system of extradepartmental expertise and control over the scientific and technical level of new projects could provide an important instrument for science policy.

[1] V. I. Lenin, "Granting Legislative Functions to the State Planning Commission", *Collected Works*, Vol. 36, p. 600.

Chapter Seven

Some Parameters and Tendencies in Science Organisation

In modern states, the administration of science is based on a study of the inner logic of its development and the evolution of its organisational forms. The importance of the latter aspect tends to grow with the development of science into an ever more highly organised form of human activity, conjugated with the balanced use of growing financial and material resources and the involvement of ever greater numbers of researchers and service personnel.

Among the most widely known models in present-day science of science is that developed by Professor Derek J. de Solla Price of Yale University, the author of the books *Science Since Babylon* and *Little Science, Big Science* and also of numerous articles dealing with the uniformities and tendencies in the growth of science. Price makes use of a biological model and considers it in a broader context ranging over all the basic parameters of science growth, not only of the "input" of science (expenditures, number of personnel), but also of the "output" (number of publications). Back in the 1950s, Price reached the conclusion that these parameters tended to grow like compound interest, doubling every 10-15 years, and having considered the inevitable socio-economic limitations of such growth, he predicted a break in the exponential curve describing such growth into a logistic curve upon the attainment of saturation. In a paper at the 13th International Congress of the History of Science in Moscow in August 1971, Price asserted that the saturation he had predicted had become a fact, above all in the

United States, and that from the stage of tempestuous growth science was moving into a stage of decline on a global scale.

All of his suggestions were met with well-argumented objections from Soviet and some foreign participants in the Congress. But I think it is well worthwhile to take a closer look at the organisational parameters of contemporary scientific activity and the tendencies in its development.

Distribution of Scientific Activity

In defiance of the requirements of the international division of scientific labour, [1] scientific activity in the modern world is distributed very unevenly among the individual countries and regions, reflecting the general unevenness of socio-economic, political and cultural development. Price takes the estimated distribution of publications in the leading natural science journals in the various countries and reaches the conclusion that each country's contribution to world science is on the whole proportional to its share of world production. More than 95 per cent of all the scientific publications come from countries with a high level of development, which account for 84 per cent of the world's gross product and 43 per cent of its population. Meanwhile, countries which account for 16 per cent of the world's gross product and 57 per cent of its population, yield less than 5 per cent of the scientific product. [2]

However, even between the countries within the first, most developed category there is an extremely large spread in the development of various forms of scientific activity: basic research, applied research and development. Nowadays, active support of basic research is something of a "categorical imperative" for any country claiming participation in the worldwide scientific and technical competition, which is inherent in science as a form of human activity. This determines the something like a standard share of the appropriations going into

[1] See Chapter Three.

[2] Derek J. de Solla Price, "Research on Research". In: *Journeys in Science. Small Steps—Great Strides*, Ed. by David L. Arm, University of New Mexico, 1967, pp. 12-14.

basic research in each country: Price estimates it at 0.7 per cent of the GNP in 1966, with a tendency to double every 10 years. This means that by 1976 it should have increased to 1.4 per cent of the GNP, by 1986 to 2.8 per cent, and so on. "Analysis of published papers shows something like this state of affairs exists in basic research." [1]

In the sphere of basic research there is virtually no international division of labour, with each country involved in the worldwide scientific competition having simultaneously to develop—within the limits of its financial potentialities—all the lines of basic research whose importance has been brought out to date. Here, too, the relataively equal share of inputs does not yield anything like the same results in volume and importance for the individual countries. If, for instance, a small or medium-size industrial country gives excessive preference—within the framework of the share of its GNP going into science—to research in thermonuclear synthesis, radioelectronics or polymer chemistry, it will have to abandon something else, say, space rocket research, so that its research balance may suffer as a result. Something similar happened to Britain in the 1960s.

Under the current worldwide competition in science, the even development of science becomes as important as its financing, being proportional not so much to the scale of national economic activity as to the international standard. But what is true of basic research is not necessarily true of applied R & D, which are separated by a

[1] Price's method of computation is simple. The number of published papers is a poor indicator of scientific productivity for individual scientists, but a fairly good one for entire countries. Accordingly, the *Chemical Abstracts* and *Physics Abstracts* are taken to compute each country's share of papers and this is compared with its share of the world's gross product. The statistical coefficients of correlation between chemistry and physics (0.88). chemistry and the GNP (0.86), and physics and the GNP (0.79) turn out to be of the same and fairly high order (Derek J. de Solla Price, *Nations Can Publish or Perish.* In: *International Science and Technology,* October 1967, New York). It should be noted, however, that Price's computations as well as the estimates of the US National Science Board fail to take account of a number of important factors like of the language barrier, classification requirements, and so on, all of which can change the picture substantially.

high cost barrier. The movement of a research project from the basic to the applied stage is attendant, on average, with a ten-fold increase in its cost, and the same thing happens when it moves from the applied stage to development. To achieve full and timely realisation of new scientific ideas, there is a need to have at least four or five scientists in applied R & D for every scientist in basic research. Far from every country has that kind of personnel potential, and this factor tends especially to increase the unevenness of distribution of scientific activity across the world. Thus, the United States accounts for about one-half of the world's R & D outlays chiefly because the lion's share of the US research budget goes into development (over 60 per cent) and applied research (about 25 per cent), while basic research gets slightly more than 14 per cent.

Given an adequate scientific and technical potential, this kind of pyramid in the distribution of efforts by the stages of research turns out to be fairly effective both from the standpoint of backing up the whole front of scientific and technical progress and in organisational terms. Joseph Ben-David, an OECD expert, says that when considering the superiority of the United States over Western Europe in this field, it is somewhat one-sided to insist on the traditional view that US science policy and organisation are pragmatic. Indeed, the conveyer mode of churning out inventions originated in the United States, and laboratories not only in private corporations but also in so-called non-profit outfits are oriented mainly upon consumer demand; science is, as a rule, closely linked with the needs of production.[1] This frequently impels scientists to tackle projects which hold promise of the most guaranteed and earliest results, to the detriment of exploratory research, which always entails a risk.

But on the other hand, these factors make basic research in the United States an organic component of the overall scientific activity system. Meanwhile, relatively little is expended in the West European countries both on basic and on applied research, with a relatively higher share going to the former. When research is not realised

[1] US private industry employs 41,000, or 26 per cent of the doctoral scientists and engineers (*1969 & 1980: Science & Engineering Doctorate Supply & Utilisation*, May 1971, NSF 71-20).

on a sufficiently broad scale, investments in applied projects make no sense. At the same time, in order to keep in step with the progress whose pace is dictated by the United States, they have to make large outlays on basic research, which puts a heavy burden on the national economy.

This state of affairs makes for some duality in Western Europe's science policy. In an effort to switch emphasis on applied R & D, it faces a shortage of funds. Falling back on the traditional emphasis on support of basic research, it has to face the same obstacle, because its results will yield an economic effect only through the medium of applied R & D. This vicious circle can be broken only through a sizable increase of effort across the whole R & D spectrum. That is exactly what the leading West European countries had been trying to do before the economic recession.

Thus, in France, R & D expenditures in 1967 came to 2.2 per cent and in 1974 to 1.7 per cent of the GNP, in Britain this proportion changed from 2.4 per cent in 1964-65 to 2.2 per cent in 1973-74, in the Netherlands from 2.2 per cent to 2.0 per cent, although it increased in Belgium (from 1.0 per cent to 1.5 per cent), in Sweden (from 1.0 per cent to 1.5 per cent), in Italy (from 0.6 per cent to 0.9 per cent) and in Japan (from 1.2 per cent to 1.6 per cent).[1] The plan was not fulfilled because of the economic crisis which broke out in the 1970s.

There have also been some changes in the FRG's science policy, which testify to a chronic lag in science and technology. From 1961 to 1971, the FRG's R & D expenditures quadrupled, to 223,000 million marks, while their share in the GNP went up from 1.3 per cent to 2.0 per cent.[2] In the subsequent years this growth continued and in 1976 the share of R & D expenditure in the FRG reached 2.4 per cent of the GNP.[3]

In the first half of the 1970s, the EEC countries' share in overall R & D outlays markedly changed, with

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[1] *The OECD-Observer,* July-August 1975; *Science Indicators 1972,* p. 110.

[2] *Politiques scientifiques nationales en Europe,* UNESCO, No. 17, 1970, p. 66; OECD International Organisation, *Collective Responses to R & D,* Paris, 1975, p. 614.

[3] *New Scientist* No. 1035, 1976.

the FRG's going up from 29.4 per cent to 37.4 per cent, the Netherlands' from 4.9 per cent to 5.6 per cent, Denmark's from 1.4 per cent to 1.6 per cent, and Ireland's from 0.2 per cent to 0.3 per cent. Meanwhile, France's share declined from 28.9 per cent to 28.1 per cent, Italy's from 7.1 per cent to 5.0 per cent, and Britain's from 24.9 per cent to 18.9 per cent. This put the FRG at the top of the list, and Britain well down, with only about half the latter's share. (*Perspectives*, September 9, 1976, pp. 14-15.)

But the most important changes in the distribution of scientific activity among the capitalist countries are connected with latest tendencies in Japan's science strategy.

Table VII-1 gives an idea of these changes. It shows that in the early 1960s, the United States was well ahead of all the leading capitalist countries both in total government R & D expenditures and, in particular, in outlays on "national defence" and space exploration. Britain alone, like the United States, allocated two-thirds of the government subsidies for military purposes, but it, too, spent only one-sixteenth of these on space exploration. But the British Government allocated three times as much on economic development, on the advancement of science, and twice as much on nuclear energy. In France, the state was relatively twice as generous as that of the United States in backing up economic research, four times as generous in its support of nuclear research, and ten times in academic research. Even the FRG Government, which was then being badgered by the Social-Democratic opposition for its lax support of science, allocated under the two latter heads, respectively, twice and 18 times as much of its funds as the USA. Meanwhile, Japan, which the USA and other countries were in the habit of regarding as a mere wholesale buyer of foreign technical know-how, spent 7.5 times more than the United States in government subsidies on economic research, and 28 times more on the advancement of science. It could have hardly managed this if it had not spent only one-sixteenth as much of government funds on defence R & D as the United States; the FRG spent one-third, and France about 40 per cent less.

At the end of the 1960s, these different orientations between the science policy of the United States and other

Table VII-1

Distribution of Government R & D Expenditures Among National Objectives, by Country, 1961 and 1969

	US	GB	France	FRG	Japan
Total in 1961 (millions of dollars)	*11,089*	*1,078*	*601*	*423*	*235*
			(per cent)		
National defence	65	65	40	22	4
Space	16	1	1	?	?
Community services	7	2	1	?	2
Economic development	4	11	8	?	30
Nuclear energy	7	15	29	16	7
Advancement of science	2	7	20	37	56
Total in 1969 (millions of dollars)	*15,847*	*4,436*	*1,798*	*1,417*	*839*
			(per cent)		
National defence	49	40	31	19	2
Space	24	4	7	6	1
Community services	12	4	3	2	4
Economic development	7	26	16	2	23
Nuclear energy	6	12	18	17	8
Advancement of science	2	13	24	39	61

Source: Science Indicators 1972, p. 103.

developed capitalist countries were basically maintained, and here and there were even more pronounced. Great Britain cut back its share of outlays on military research by 26 per cent, and increased the share of outlays on economic research by 15 per cent, while nearly doubling (to 13 per cent) government subsidies for the advancement of science (academic research). France reduced the share of its military R & D finance by 9 per cent, doubled

that of economic research (to 16 per cent) and increased appropriations for the advancement of science to 24 per cent. On this latter indicator, Britain spent 6.5 times more than the United States, France 12 times, the FRG nearly 20 times, and Japan over 30 times more.

A work by the Japanese student of science, Mitsutomo Yuasa of Kobe University, entitled "Center of Scientific Activity: ts. Shift from the 16th to the 20th Century", is of some interest for analysing the distribution of scientific activity in the world, and its tendencies and perspectives. Relying on research by J. D. Bernal [1] and R. K. Merton, [2] Yuasa enlisted the efforts of members of the Mokuyo kai group at Kobe University to reach the following conclusions. Taking as the centre of scientific life a country whose scientists produced more than 25 per cent of the world's scientific achievements in a given period, since the 16th century this centre moved as follows [3]:

1540-1610—Italy (Florence, Venice, Padua)
1660-1730—England (London)
1770-1830—France (Paris)
1810-1920—Germany (Berlin)
1920 and later—USA (New England, California).

Yuasa says that this was a movement of the centre of pure science personified by men like Galileo, Newton, Lavoisier, Laplace, Gauss, Liebig, Helmholtz and Hubble. In the broader context of scientific and technical advance, the chronological framework has markedly shifted: thus for Britain, for instance, it extends to the 19th and

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[1] John D. Bernal, *Science in History*, London, 1954.

[2] Robert K. Merton, *Social Theory and Social Structure*, New York, 1949.

[3] His sources were: 1) Ludwig Darmstaedter, *Handbuch zur Geschichte der Naturwissenschaften und der Technik*, Berlin, 1961; Mitsutomo Yuasa, *Kagaku-Bunka-shi Nenpyo*, Tokyo, 1960; *Heibonshas Kagaku-Gijutsu-shi Nenpyo*, Tokyo, 1956; 2) *Webster's Biographical Dictionary. A Dictionary of Names of Noteworthy Persons with Pronunciations and Concise Biographies*, Springfield, Mass., 1951; Albert M. Hyamson, *A Dictionary of Universal Biography of All Ages and of All Peoples*, London, 1951; 3) Data on Nobel Prize Winners from 1901 to 1960. Two other sources—data on the number of university graduates in the exact sciences and on publications of scientific papers in the periodical press—were not used by the author because of the magnitude of the task of collecting and analysing them all over the world.

20th centuries. This seems to apply to the other countries as well. But Yuasa does not consider the dynamics of scientific and technical activity, confining himself to science in the proper sense of the word. This is clearly a retreat from the point reached by J. D. Bernal, who considers the distribution of the centres of technical and scientific activity with the interaction between science and technology, on the one hand, and with the character of society in each epoch, on the other.

Yuasa identifies the following three stages: 16th-17th centuries—the origination of modern science (Italy); 17th-20th centuries—the flourishing and decline of science in Western Europe (Britain, France and Germany), and beginning with the 20th century, the origination of the science of the future (United States).

One will note that this scheme completely ignores the major scientific achievements and developments which do not fit into the author's geographical or chronological framework. Thus, it leaves out the epoch-making works and discoveries of Pasteur, Becquerel and the spouses Curie (France in the late 19th century); Rutherford and Thomson (Britain, 19th-20th centuries); Einstein (Switzerland, Germany, USA, 20th century), Watson, Crick and Wilkins (Britain, USA, 20th century), among others, without which it is hardly possible to judge about the world's scientific life and its dynamics. This equally applies to the historical contribution to world science by East European scientists (Copernicus, Poland, 16th century), and especially Russia's in the 19th-20th centuries (Lobachevsky, Mendeleyev, Sechenov, Pavlov, Vernadsky, and others). Yuasa himself remarks that it is impossible to determine the future of science in the United States without comparing it with Soviet science, as will be seen, in particular, from the data on the award of the Nobel Prizes. But does it not follow from this that it is hard to judge about the development of world science and its perspectives without considering the achievements of scientists in the USSR?

The fact that because of the language barrier and for various other reasons, Russian and East European science has not been adequately reflected in the sources used by Yuasa does not make his conclusions any more authentic. The same also applies to his separation of

scientific activity and scientific and technical activity as a whole. After all, the latter is not just a "historical background" which may be neglected, but an extremely important source of new scientific ideas and scientific creativity in the proper sense of the word.

Finally, although Yuasa takes France as an example in an effort to go to the social roots of the flourishing of science in that country in this or that period, his efforts do not go beyond a reduction of these roots to an "anomy" in social structure, according to Merton. Yuasa says that the only reason for the end of another round of flourishing scientific activity and transfer of scientific activity to another country is the ageing of the leading scientists, who are chronically left without followers and continuators. But this is at variance with the historical fact that major scientific schools have far outlived their founders (the Rutherford school, the Pavlov school, etc.), and this Yuasa's scheme does not take into account. [1]

Consequently, Yuasa, who suggests that his model should be designated as the "Yuasa regularities", neglects various facts and objective tendencies in the world's scientific activity, of which he must surely be aware. The result is a simple and convenient historical scheme: origination, rise and decline of modern science in the West European countries (16th-20th centuries) as the prelude to the origination of the science of the future in the United States in the 20th century. What happens next?

According to Yuasa, the future of US science can be predicted through an analysis of the periods in which science flourished in Italy, Britain, Germany and France, and also of the data on Nobel Prize Winners, by making a comparison of the number of winners in the United States and the USSR. Yuasa estimates that the periods in which science flourished in the West European countries lasted 70 years in Italy and Britain, 60 years in France, and 110 in Germany, which gives an average period of 80 years. Consequently, Yuasa concludes, the period in which US science will flourish is 1920 to 2000, assuming that US science has been developing according to the same laws as European science.

[1] M. Yuasa, "Center of Scientific Activity: ts. Shift from the 16th to the 20th Century". In: *Japanese Journal of the History of Science,* January 1962.

Yuasa reaches the same conclusion by extrapolating the distribution of Nobel Prize Winners between the United States and the USSR, and other countries. [1]

Where then will the centre of flourishing world science move to after 2000? We find no direct answer to this question in Yuasa's work, which was written in 1962. But his paper at the 13th International Congress of the History of Science held in Moscow in August 1971 does shed some light on the matter. His paper was entitled: "The Growth of National Scientific Communities in Japan." [2] The author uses a metaphor to liken the process to the life of a butterfly that begins by being an ovum, an insect that undergoes a perfect metamorphosis from an ovum through a green caterpillar and a cocoon, and then a mature butterfly. "We wonder how a noxious worm that creeps on the earth can grow into a beautiful butterfly that dances in the air. Biologists may explain the process of metamorphosis as the effects of corpora-allata, a hormone secreted from the prothorax glands."

In accordance with this metaphor, Yuasa suggests the following periods:

a) "Green caterpillar" period: scientific communities in Japan from the ancient days to the Tokugawa or Edo period, mainly founded upon imported classic Chinese culture together with Buddhist culture that had come over the Continent of Asia.

b) "Chrysalis" period: scientific communities during the days when Japan was almost closed to foreign culture from 1639-1853.

c) "Butterfly" period: scientific communities in present-day Japan since the year 1853.

In each transition from one period to another, it was foreign culture and science that had acted as the hormone: first it was Chinese, then Dutch, then Anglo-American, German and French. In the Meiji epoch, the British and the Americans were the most numerous (73 and 101 specialists, respectively) followed by the Germans (52,

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[1] M. Yuasa, "Center of Scientific Activity: ts. Shift from the 16th to the 20th Century". In: *Japanese Journal of the History of Science,* January 1962.

[2] M. Yuasa, "The Growth of National Scientific Communities in Japan". In: *Proceedings of the XIII International Congress of the History of Science,* Section II, pp. 240-42.

mainly in medicine, and the natural and technical sciences), the French (36, mainly in military matters), the Dutch (14), the Italians (7) and the Russians (5). Other countries (Austria, Belgium, Switzerland, Sweden and Canada) made 11 specialists available to Japan, mainly in the natural and the exact sciences and also in religion.

"Japan," Yuasa says in conclusion, "has completed growth from a green caterpillar through a chrysalis into a beautiful butterfly. From now on, it will create original scientific communities in the field of social sciences as it heretofore has in the field of natural science and technology." [1]

Consequently, there is good reason why Japanese students of science have been studying the movement of the centre of the world's scientific activity, together with the back-up analysis of the evolution of this activity within the Land of the Rising Sun itself. [2] The remark concerning the chief hormone of the evolutionary metamorphosis has already become a definite line of action. The traditional use of foreign experience was transferred from the general cultural and scientific fields into the field of applied science and technology, in particular. The "hormone" has worked. Let us recall that the leap in the key areas of modern production which carried Japan to second place in the capitalist world after the United States was based on an unprecedentedly extensive and skilful purchase of advanced foreign scientific and technical know-how. Up until 1970, Japan's GNP trebled every 10 years, but it had a chronic deficit in the patent and licence trade and a lag in its own research facilities. In the late 1950s, the share of the GNP which Japan put into R & D was less than one-half of that of the United States. It was even farther behind in government financing of R & D. [3]

But in the 1960s and especially in the 1970s, the situation began to change. Japan had substantially exhausted its manpower reserves and was faced with the

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[1] Ibid., pp. 240-44.

[2] Ibid., Y. Fukushima, "The History of the Development of the Organisation for Promotion of Science and Technology in Japan after the World War II", pp. 244-51.

[3] *Evolution of the Forms of Science Organisation in the Developed Capitalist Countries,* Moscow, 1972, p. 569 (in Russian).

need markedly to intensify its production in scientific and technical terms. At the same time, there was a sharp rise in the cost of patents and licences on the world market (this being unwittingly caused by the whole of Japan's former policy), so that their purchase on the old scale became unprofitable. From the second half of the 1960s, Japan began to work out five-year R & D programmes, and in the 1970s their scale and pace were sharply stepped up. According to official estimates, Japan was planning R & D funding increase by 25 per cent a year, to reach 3 per cent of the GNP by 1975. [1] According to some forecasts, by the end of the current decade Japan was expected to multiply its scientific and technical potential several times over, to become one of the leading science countries in the world.

Assuming that this will be so, one can easily envisage a period in which Japan will start vigorously to export not only transistors, ships, cars and synthetics, but also original scientific and technical ideas on the markets of the capitalist world. [2] It is highly characteristic that in the early 1970s (with a 30-fold edge over the USA in the share of government outlays on academic science), 29.3 per cent of Japan's science budget went into basic research (twice as much as that of the USA), 28.5 per cent into applied research and 42.2 per cent into development. [3]

Consequently, there is a gradual change in the balance of strength in the scientific and technical and the economic fields, but the unevenness of the development itself continues to be a perennial feature of the system of scientific and political competition. This unevenness is most acute between the industrialised and the developing countries. According to UNESCO, the latter's GNP in 1970 was only one-fifth, and the science budget one-ninth of the former's. The share of the GNP going into R & D in

[1] *Chemical Engineering Progress* No. 3, 1971, p. 27.

[2] Jéquier regards Japan as a country conducting an active technical policy and successfully combining it with direct and feedback connections both with scientific and industrial policy. (Nicolas Jéquier, "La fin de la politique de la science". In: *Revue économique et sociale* No. 2, Lausanne, June 1973, pp. 191-94.)

[3] *Études et documents de politique scientifique* No. 18, Paris, UNESCO, 1971, p. 170.

the developing countries came to only 1 per cent, as compared with the 1.8 per cent in the industrialised countries. Price has estimated that the less developed countries, which together produced 15.8 per cent of the world's gross product (1964), accounted for only 0.8 per cent of all scientific papers in physics (1961) and 4.6 per cent of the papers in chemistry (1965).[1] Price says that there are still vast areas in the world where less than one person per million of population is engaged in scientific activity, and where, consequently, the development of higher education, the growth of research, and the use of science by society could continue at an ever faster pace and without any special impediments.

But a more widely accepted view is that the developing countries do not need to have scientific, technical and economic progress. Professor Jay W. Forrester, who has produced the "social dynamic" conception and a model of world development for the hundred years ahead of us, claims that there is now a growing trend to question the role of science and technology as the saviours of mankind. "There may be no realistic hope of the present underdeveloped countries reaching the standard of living demonstrated by the present industrialised nations.... From the long view of a hundred years hence, the present efforts of underdeveloped countries to industrialise may be unwise. They may now be closer to an ultimate equilibrium with the environment than are the industrialised nations. The present underdeveloped countries may be in a better condition for surviving forthcoming worldwide environmental and economic pressures than are the advanced countries. If one of the several forces strong enough to cause a collapse in world population does arise, the underdeveloped countries might suffer far less than their share of the decline because economies with less organisation integration, and specialisation are probably less vulnerable to disruption."[2]

We find such a conception hardly acceptable. After all, the maintenance of the existing gap in economic, scientific and technical development levels is fraught with much greater dangers for the existence and devel-

[1] Derek J. de Solla Price, *Nations Can Publish or Perish.*
[2] Jay W. Forrester, *World Dynamics,* Cambridge, Mass., 1971, pp. 12-13.

opment of mankind than those dealt with in Forrester's *World Dynamics*. Indeed, the developing countries themselves have resolutely decided to bridge the gap as soon as possible, regarding scientific and technical progress as the surest way to solve a whole spectrum of world problems, ranging from the exhaustion of energy and food resources and the ecological danger to population growth.

The UNESCO report, *Science and Human Needs*, emphasised the growing importance of science and technology for the developing countries. Because of their scant resources for development, there is a need in these countries to plan scientific and technical progress. But it would be wrong to believe the report says, that such planning could be achieved through a direct transfer of the mechanisms of science policy from the industrialised countries. Each country should rather develop its own mechanisms of planning in accordance with its own needs and in such a way as to ensure through their medium the attainment of its priority goals. This view is also favoured by the Swedish Professor St. Dedijer, who insistently emphasises the uniqueness of science policy in the developed countries, and the specific social and cultural environment. He believes that this makes any simple "importation" by the developing countries of the problems and solutions produced by the industrialised countries' science policy highly unpromising. [1]

Rand Corporation's Hans Heymann urges the need for substantial corrections in the light of the specifics in the developing countries (taking US scientific and technical aid to Turkey as his example). [2] He subjects to serious criticism the attempt to transplant in the developing countries the formalised methods of the centrally oriented systems engineering as practised in the United States. He says: "At the risk of some over-simplification, I would assert that, viewed from the perspective of a developing country, there are only two points that need to be made about the tools of systems engineering:

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[1] St. Dedijer, "National R & D Policy as a Social Innovation". In: *Management of Research and Development,* Paris, 1972, p. 104.

[2] H. Heymann, "Promoting the 'D' in R & D: Dubious Models and Relevant Strategies". In: *Management of Research and Development,* Paris, 1972, pp. 111-36.

(1) they were created to cope with a very special set of problems in a very special environment, and (2) more often than not, even within that special environment, they don't work." [1]

Turkey's example shows that in the conditions obtaining in developing countries the "centralistic symbiosis" of state and private enterprise, which is dictated by the systems approach, is totally unrealistic. That is why Heymann suggests that it should give way to strategic concentration and selectivity. "The strategy, very simply, is to concentrate substantial effort on building a few islands of scientific and technological excellence, rather than to diffuse all effort over the entire sea." [2]

N. Jéquier, Consultant to the Directorate for Scientific Affairs, OECD, goes much farther. He ridicules the "magic of numbers" used in science policy in the 1960s, when "in several highly industrialised countries, one of the main objectives of national science policy ... seems to have been to reach the magical '3 per cent' figure of the United States, whereas many developing nations have come to accept the '1 per cent' figure as a symbol of technological take-off". [3] But the "complementarity principle" declares its right in science policy, too. As in economic and social policy, ever greater importance in science policy attaches to the external final goals, as compared with the internal ones, which had up to now been paramount. The need for such a re-orientation is characterised by Jéquier as the need for a Marxist revolution. He writes: This transition from internal to external finalities may contribute to making economic policy and science policy more responsive to the real needs of society, however difficult to define these needs may be. Such a transition is necessary not only in the highly industrialised countries, but also, and perhaps even more so, in the less developed countries where science policy tends to be even more inner-directed and self-centred.... It seems clear that the external finalities of science policy or economic cannot and should not be defined solely in terms of the preferences of a few privileged nation-states: they have to be

[1] Ibid., p. 116.
[2] Ibid., p. 128.
[3] N. Jéquier, "New Problems in Science Policy". In: *Management of Research and Development,* Paris, 1972, p. 166.

Table VII-2

The Development of the Scientific Potential of the USSR's Union Republics

Republic	Number of higher schools		Number of scientific institutions		Number of research personnel (1,000)		Number employed in science and scientific services (1,000)	
RSFSR	72 *	462 **	231 *	2,970 **	8 *	688 **	40 ***	2,384 **
Ukraine	27 *	138 **	41 *	814 **	2.5 *	137.5 **	9 ***	448 **
Byelorussia	0 *	28 **	2 *	178 **	0.1 *	24.1 **	1 ***	68 **
Uzbekistan	0 *	38 **	2 *	188 **	0.1 *	26.3 **	1 ***	64 **
Kazakhstan	0 *	44 **	0 *	207 **	0 *	27.8 **	1.5 ***	124 **
Georgia	1 *	18 **	10 *	194 **	0.6 *	21.3 **	1.8 ***	50 **
Azerbaijan	0 *	13 **	2 *	142 **	0.1 *	18.2 **	0.5 ***	39 **
Lithuania	0 *	12 **	1 *	88 **	0.06 *	9.7 **	0.6 ****	31 **
Moldavia	0 *	8 **	0 *	68 **	0 *	6.0 **	0.1 ***	23 **
Latvia	1 *	10 **	1 *	101 **	0.05 *	9.2 **	0.5 ****	27 **
Kirghizia	0 *	9 **	0 *	65 **	0 *	6.3 **	0.1 ***	30 **
Tajikistan	0 *	8 **	0 *	61 **	0 *	5.5 **	0.1 ***	18 **
Armenia	0 *	12 **	0 *	101 **	0 *	13.9 **	0.7 ***	35 **
Turkmenistan	0 *	5 **	4 *	58 **	0.008 *	3.8 **	0.2 ***	15 **
Estonia	4 *	6 **	4 *	72 **	0.14 *	5.0 **	0.5 ***	18 **

* 1913/14, ** 1971, *** 1926, **** 1940

Source: The Economy of the USSR. 1922-1972, pp. 499-692.

defined in a worldwide context, however difficult this may seem." [1]

The socialist countries have gained much historical experience in overcoming, in practical terms, the unevenness in the spread of scientific activity among the regions. Here, the world's first socialist country, the USSR, holds a leading place.

Table VII-2 shows that before the Great October Socialist Revolution there was a glaring gap between the levels of scientific potential and, consequently, between the distribution of scientific activity among the various national regions of what is now the USSR. In 1913/14, Russia had 72 higher schools and 231 scientific institutions, while the number of research personnel came to about 8,000. The Ukraine had 27 higher schools, 41 scientific institutions and 2,500 researchers. In other parts of the country, the number of researchers was extremely small. In Georgia, which had 10 scientific institutions, the number of researchers did not exceed 600, while Turkmenia and Estonia, with four scientific institutions each, had eight and 140 researchers, respectively. Let us recall that Estonia and the other Baltic republics—Latvia and Lithuania—joined the USSR only in 1940, but by then the number of higher schools in Estonia had increased from four to five, of scientific institutions to 26, and of researchers to 500. For Latvia, the 1940 figures were, respectively: seven, 39 and 1,100; and for Lithuania seven, 20 and 600. [2] In the early years of Soviet power, a resolute policy was laid down to accelerate the build-up of research facilities in the outlying non-Russian areas, a stepped-up development of scientific activity along the vertical in the non-Russian republics designed to pave the way for its horizontal flourishing across the whole country. The latter helped to prepare a well-equipped launching pad for a general upswing among the peoples of the USSR towards the summits of knowledge.

Thus, in 1971, the Kazakh Republic, which before the revolution did not have a single higher school or scientific institution, had 44 higher schools and 207 scientific

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[1] N. Jéquier, op. cit., pp. 168-69.

[2] *The Economy of the USSR. 1922-1972*, pp. 605, 606, 629, 630, 679, 691, 692.

institutions, employing 27,800 scientific workers. The number of those working in science and scientific services had gone up almost 83-fold (from 1,500 in 1926 to 124,000 in 1971). Scientific activity grew at an equally rapid pace in Moldavia, Kirghizia and Tajikistan, where the figures increased, respectively, 230-fold, 300-fold and 180-fold, while the figure for the RSFSR was about 60-fold.

These quantitative parameters of the development of scientific activity have a very important qualitative aspect. The highly skilled researchers and teachers from Moscow, Leningrad and Kiev did not simply "transfer" knowledge from the centre to the non-Russian areas, but helped to foster national science personnel in these republics. As a result, the country's scientific life gained exceptionally in the diversity of research and pedagogical styles, methods and trends. In 1971, the Presidium of the USSR Academy of Sciences awarded the Lomonosov Gold Medal—the highest award in the natural science—to Academician V. A. Ambartsumyan, a remarkable Soviet astronomer and astrophysicist, President of the Academy of Sciences of the Armenian Republic, and the author of a new theory of light dispersal in turbid environments, and the theory of statistical studies of interstellar absorbing nebulosities.

That same year, the USSR Academy of Sciences awarded the Gold Medal instituted in honour of the well-known Russian astrophysicist F. A. Bredikhin, to Corresponding Member of the Academy of Sciences of Estonia G. G. Kuzmin for a series of works on theoretical stellar dynamics, which continued and successfully elaborated Academician Ambartsumyan's idea of the evolution of stellar clusters. Estonian astrophysics, with its long-standing tradition of the Tartu school, headed by Academician Naan, stretched a hand of cooperation across the whole country to Armenian astrophysics at its centre in the Byurakan astronomic observatory.

In another part of the Soviet Union, at the International Latitude Station named after Ulugbek in Kitab (70 kilometres from Samarkand) the operation of a giant zenith telescope is directed by A. M. Kalmykov. This highly sophisticated instrument is situated on the spot where 500 years earlier the great Uzbek scientist, Ulugbek, a grandson of the terrible Tamerlane, had had his

famous observatory, which was discovered by the Russian archaeologist V. L. Vyatkin.

The scientific achievements of the Union republics have won broad international renown, and this is reflected in the election of many of their scientists to membership of foreign scientific societies and organisations. Thus, Academician Kh. M. Abdulayev, who is a member of the Uzbek Academy of Sciences and a Corresponding Member of the USSR Academy of Sciences, has been elected a member of the Mineralogical Society of Great Britain and Ireland, and of the Geological Society of France. Academician D. M. Guseinov of the Azerbaijan Academy of Sciences, and Academician G. S. Davtyan of the Armenian Academy of Sciences, Corresponding Member of the Georgian Academy of Sciences M. K. Daraselia, and Corresponding Member of the Kazakh Academy of Sciences U. U. Uspanov have been elected members of the International Society of Soil Scientists. Academician J. M. Jurginis of the Lithuanian Academy of Sciences has been elected member of the National Geographic Society of the USA. This is a list that could well be continued. [1]

The TV model [2] for overcoming the unevenness of scientific activity among the peoples of the USSR has transcended its state borders.

Mongolia, a country of extensive nomad animal breeding only a half-century ago, has been helped first by the Soviet Union and then by other socialist countries to move from feudalism to socialism and to the modern scientific and technical revolution. In 1962, Mongolia joined the Council for Mutual Economic Assistance (CMEA), whose Comprehensive Programme of socialist economic integration contains a special section setting out the ways to induce accelerated growth and higher efficiency in Mongolia's economy. It took the Mongolian specialists and scientists trained in the socialist countries of Eastern Europe, notably, the USSR, and relying on assistance from these countries only a short historical period to lay the foundations for their country's educational, scientific and technical development. This was a tangible contribu-

[1] See, S. G. Korneyev, *Soviet Scientists, Honorary Members of Foreign Scientific Institutions,* Moscow, 1973 (in Russian).

[2] See Chapter One.

tion to its socio-economic and cultural progress. Thus, in 1973/74, Mongolia's six higher schools had 10,100 students (as compared with 1,500 in 1950). The number of those working in science and scientific services increased from 1,500 in 1960 to 4,900 in 1973.[1] In 1972 alone, the number of persons holding scientific degrees increased by 15.7 per cent.[2] This helped to increase the volume of Mongolia's aggregate social product between 1962 and 1973 by 80 per cent, and the national income, by 50 per cent. Its gross industrial output went up 150 per cent, while its share in the production of the national income rose from 14 per cent in 1960 to 23 per cent in 1972.[3] In that period, the index of labour productivity for industrial personnel went up by more than 50 per cent. An impetus was given to cultural development. In 1972, Mongolia had 36 newspapers and 32 journals with a total printing of 1.1 million copies, while audiences at various entertainment establishments were 3.2 per cent up on the preceding year.[4]

Equally indicative are the achievements of the ongoing scientific and technical cooperation between the Soviet Union and other CMEA countries (especially the GDR, Poland and Czechoslovakia) and the Republic of Cuba, which are helping the country to move into the front scientific and technical ranks in Latin America.

Centralisation, Decentralisation and Concentration

The distribution of scientific activity in the modern world clearly testifies to the high level of R & D concentration in the most industrialised capitalist and socialist countries, above all, the United States and the Soviet Union. But within each of these countries the problem of combining scientific activity concentration with the

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[1] *Statistical Yearbook of the CMEA Member Countries*, 1974, pp. 407-23; *The World of Socialism in Figures 1972* (Reference Manual), Moscow, 1973, p. 128 (in Russian).

[2] Ibid., p. 130.

[3] Ibid.

[4] Ibid., p. 138.

necessary measure of centralisation and decentralisation is being tackled above all in the light of social factors.

In practice, the evolution of the forms and methods of science organisation is subordinate not so much to the inner logic of its own development as to the logic of society's development in which the historical uniformity makes headway through a multiplicity of casual factors. In the capitalist countries, the tendencies towards centralisation and decentralisation in organising scientific activity are patterned on the interplay of monopoly and competition within the economy of state-monopoly capitalism. Just as centralisation is opposed to decentralisation, so étatisation—the highest form of monopolisation—is opposed to the tendency towards reprivatisation, that is, a return or transfer of state property to private ownership. These tendencies are in a state of dynamic equilibrium, which does not allow the complete exclusion of either of these in favour of the other. What is more, these tendencies feed upon each other. Capitalist étatisation is possible only on the basis of private property in the means of production, the foundation of bourgeois society and the state. For its part, reprivatisation amounts to nothing more than the transfer of various units of state property to private ownership.

One will easily understand, therefore, why the establishment of a ramified machinery of government agencies to direct science in all the developed capitalist countries is directly continued and supplemented with support for nongovernmental, private, profit and nonprofit scientific outfits.

Ever more frequently, the dynamic equilibrium between centralisation and decentralisation tends to shift towards centralisation and étatisation, reflecting the overall trend in the present-day historical process, the trend towards the growing socialisation of the whole mechanism of social reproduction. But under capitalism this trend has to make headway across a great many obstacles, so that it is now and again forced to run a reverse course. The trends in science organisation (as in the economy) change most markedly in "extreme" conditions, under the impact of military-political and economic-outlook factors. In the atmosphere of all kinds of "national crises" there is as a rule evidence of a shift towards

state centralisation, with the trend towards centralisation ever more clearly gaining the upper hand. [1]

World developments have also acted in the same direction. A group of OECD experts reached the significant conclusion that more than 60 per cent of the US scientific and technical effort and over 80 per cent of US government appropriations for these purposes were directly or indirectly connected with the "external challenge". [2]

But while the resultant is directed towards centralisation, its combination with decentralisation continues to be meaningful and to influence the mechanism of science-activity administration.

The need for this combination is rooted in the demands made on organisation and management at the level of the primary research team. Professor J. E. Walters wrote: "With decentralisation in leading and managing, a group leader can manage a larger number of scientists and paradoxically, at the same time increase the quality of the management from the scientist's viewpoint. Decentralisation hence could be a means of decreasing the cost of R & D management and of increasing creativity and productivity. If management costs are decreased through decentralisation, by more definitely placing responsibility and authority where decisions are made and action takes place, by an increase in the span of management to a larger number of scientists, there appears a paradoxical situation of seemingly increasing centralisation of more people reporting to one leader and the de-

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[1] The Anglo-Saxon legal system has left its mark on the evolution of the forms of science organisation in the United States and Britain. Within its framework any substantial shift is recorded in precedents which legalise the existence of the newly established scientific organisations and science management agencies. New legal rules and new forms of organisation and management of scientific activity to supplement the old forms are constantly being set up, with a growing diversity and pluralism of organisational forms which are especially characteristic of the United States, where the state organisation is closely interwoven with capitalist competition. In the recent period, competition has been sharpened by the cut-backs in appropriations for science. In France, the étatist organisation of science is a historical tradition rooted in the Napoleonic period.

[2] *Organisation for Economic Cooperation and Development. Reviews of National Science Policy. United States,* Paris 1968, p. 36.

centralisation of giving each scientist more authority and responsibility to make decisions." [1]

The right mix of centralisation and decentralisation is a critical problem at the level of government science policy. At the present stage in the development of science organisation, its solution in general terms boils down to a combination of centralisation within the science administration system and decentralisation within the research system. Obviously, however, excessive centralisation of science administration is just as inadvisable as excessive decentralisation in research. There is good reason, for instance, why steps are being taken in the recent period to reduce the number of science management agencies, while extending their competence, in the United States, where spontaneous evolution has led to the establishment of a number of agencies for the management of science within the administrative branch under the President, in the departments and offices, and in Congress. One could say, in a sense, that the desired *mix* of centralisation and decentralisation will be achieved only through a sufficiently high level of *concentration* both in scientific activity itself and in the management of it.

In the USSR, the 25th Congress of the CPSU had good grounds for bringing to the fore in science organisation and administration the concentration of efforts and resources on the crucial lines of scientific and technical progress. Without such concentration, centralisation may well rule out the multivariant approach which helps to optimise selection, while decentralisation may excessively disperse the efforts over a multiplicity of "equivalent" variants.

The growing tendency towards centralisation under the impact of external factors is countered by a relaxation of this tendency under the impact of internal factors, which include above all the growing role and importance of basic research.

This depends substantially on the special status of basic research in the atmosphere of the "information crisis". This crisis, apparently connected with an "overproduction" of scientific publications, has an effect on published information, that which has already appeared

[1] J. E. Walters, *Research Management: Principles and Practice*, Washington, 1965, p. 197.

in the press. But fundamental scientific knowledge which is gained at the forefront of science, frequently becomes available to other scientists before publication, being conveyed in the form of verbal statements, private letters, preprints, and so on. Characterstically, Price, who believes the number of quotations from published papers to be the most reliable indicator of scientific development, [1] says that in fact scientists do not publish their most valuable ideas, and that it is the technologists and not the scientists who have been complaining about the "information crisis". [2] Indeed, the very idea of such a crisis is based not so much on an excess of information as on the difficulties of finding it amidst the information noise whose level frequently turns out to be higher than that of the useful signal.

It would be a great oversimplification to say that the "science vogue" has led to a clogging up of the channels of scientific information with pseudoscientific publications: this is an old phenomenon. [3] The point is that as the most open and easily accessible layers of scientific knowledge are "worked out", the labour-intensiveness of "extraction" tends to grow, together with the inputs in personnel and resources, and most often in the ancillary operations and the infrastructure which provide the back-up for research proper. This is what is reflected in the accelerated growth of the tiers of scientific and technical information which are connected mainly with methods and techniques of scientific activity. It is these that engender the "information crisis". But the attendant inputs should not be regarded as useless, if only because these are the technico-methodical tiers on which effective means were created to overcome the crisis situation, the means for automating mental labour—electronic computers.

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[1] Price had even tried to forecast scientific discoveries by analysing the pattern of mutual references (*20th National Conference on the Administration of Research,* University of Florida, 1966, pp. 45-51).

[2] *Evolution of the Forms of Science Organisation in the Developed Capitalist Countries,* p. 10.

[3] Back in 1927 *Nature* published an article "Movements of the Lower Jaw of Cattle During Mastication", written by Dr. P. Jordan and R. de L. Kronig just for fun. (*Nature,* December 3, 1927, p. 807.)

The extensive use of computers in research and information opens up new horizons not only for applied, but also for basic research. The display and interface devices being worked out for the three-and-a-half and especially the fourth generations of electronic computers, which help to establish direct communication between man and machine, may well further relax the researcher's dependence on the slow and cumbersome procedure of recording his results in print. This will help substantially to make the forms of research organisations more flexible and fluid, thus making the whole of it "academic", in the good sense of the word, approximating to the organisation of basic research. Some insist that lack of organisation is the best kind of organisation for basic research, in the formal sense, at any rate. Although it is hard to accept this assertion in categorical terms, it does contain a grain of truth. The organisation of basic research should have properties which make it virtually imperceptible. In other words, it seeks to develop into a self-organising system, in which the high development of inner self-regulation compensates the impossibility and inadvisability of external management. Thus, in Chapter Four, I said that academic organisations specialising in basic research increasingly operate as structure-forming elements for new science centres.

The establishment of the Soviet system of science organisation signified a substitution of conscious for spontaneous evolution in the field of science organisation, and that was not a historical accident by any chance.[1] Under different social conditions, the protracted, accelerating and complexifying process in the formation of a scientific science-organisation system displayed an irreversibility, similar to James Dana's irreversibility of cephalisation. Let us recall that the functional differentiation of organs and tissue, and especially the progressive development of the nervous system led to the formation of the brain, which took over the higher functions of controlling the organism. V. I. Vernadsky, who repeatedly referred to this profound "empirical generalisation" by the American scientist, derived from the cephali-

[1] Robert K. Merton, *Social Theory and Social Structure*, pp. 323-29.

sation principle his conception of the noosphere, where the scientific organisation of society and of science itself has a prominent place.[1] Indeed, at the turn of the century, with the growing differentiation and integration of the sciences, the approximation of scientific theory and the needs of practice, the growth of concentration and centralisation of scientific activity and the emergence of national science organisations of a semi-governmental character, individual government agencies for the administration of science appear. From then on, the pace of development tends markedly to accelerate. Over a half-century, and under the impact of the demands of practice, made urgently imperative by the First and, especially, the Second World War, these agencies take shape as a system of government administration of science. On this basis is shaped the mechanism of science policy, acquiring the importance of a new function of the state in the age of the scientific and technical revolution. The fundamentally new conditions of social development which took shape in the USSR have made it possible to effect the transition from backwardness to progress in the shortest historical period.

The Soviet Union's launching of the first artificial Earth satellite in 1957 provided an impetus for the further evolution of the forms of organisation and administration of science throughout the world.

In the USSR, the system of state administration of science has restructured into a single system the network of science centres and institutions, exerting an active and purposeful influence on the structure and course of scientific life in the country as a whole. The example and experience of science planning in the Soviet Union had a tremendous influence on the organisation of science in all countries, including the United States. Up until recently, US ruling circles maintained a definite degree of decentralisation, which was compensated by a high concentration of scientific effort and management of it. The stochastic system of informal ties compensating for the defects of formal ties has an unobtrusive but important place in

[1] Elaborating on this idea one could say that like cephalisation, the need and possibility for the formation of organs to control it originated in the spontaneous evolution of the forms of science organisation.

this area. But from the early 1970s on, there has been evidence of a trend in the United States to centralise the administration of science.

The National Science Foundation (NSF) has the role of central expert and financing organisation in the field of science policy, and above all in the direction of basic research in the country. It is headed by a National Science Board, which is appointed by the President with the approval of the Senate. This Board is composed of persons who are not employed by the federal administration, the only exception being the Director of the Science Foundation, who is a government official, also appointed by the President. In his activity, he is accountable both to the US President and to the National Science Board.

In contrast to the other federal agencies, whose research programmes are subordinate to their basic sociopolitical functions, the main task of the NSF is to maintain the proper balance between the various stages and lines of research in order to guarantee the overall health and viability of scientific activity in the United States.

However, the attempt to make the NSF evaluate the overall effectiveness of the federal and national effort in civilian R & D in attaining national goals through the use of science and technology, and give recommendations on the political and programme action necessary to achieve these goals was not a success. In the second half of the 1970s, there was growing disappointment in the United States over the reform of the science policy apparatus carried out under the Nixon administration, and mounting demands for a return to its old structure and functions.

Saturation or Pulsation?

At the end of the 1960s and the beginning of the 1970s, there was ever more pronounced expression of disappointment in the United States and some other capitalist countries over the role of science in society. [1] For the

[1] According to F. Crick, Nobel Prize Winner in physiology, the reasons were several. Science was becoming too costly, which is why people wanted to know what they were paying for. Those who are not immediately involved in science do not

first time since the 1940s, there was a sharp reduction in the growth of appropriations for the development of science and technology, especially from government funds. Actual appropriations were reduced even in absolute form, because the annual increment which remained was being "eaten away" by the rapid growth of inflation. Unemployment appeared among scientists, running to tens of thousands and becoming stagnant. A report issued by the US President's Task Force on Science Policy, published in April 1970, noted the discrepancy between the problems facing society and the instruments available for their solution. [1]

The scornful attitude to science and technology, which the authors of the report said was to be found chiefly among the unemployed, the hungry, the Blacks and the young, had in fact affected the ruling circles and even those who worked in science and technology, were actually responsible for science policy, and closely allied with these circles.

In the atmosphere of the monetary-financial and economic crisis in the late 1960s and early 1970s, the ruling circles were ever more seriously exercised over the question of the returns on R & D inputs. While scientific activity in the United States had assumed a grand scale over the past decade, it did not become any more reliable as a business. Tens of billions of dollars annually expended on R & D did not yield the expected political and economic benefits and did not prevent the aggravation of serious problems at home and abroad. By the end of the 1960s, these expenditures came close to $30,000 million a year, or 3 per cent of the GNP. What were the returns? It is true that the doubling of the GNP in the course of the 1960s had been effected with an increase in man-hours worked by only 9 per cent. It is also true that the balance in the exchange of technology (patents, licences and know-how) between the United States and other countries did not merely remain

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obtain any spiritual satisfaction from it. The third reason is the harmful consequences of the use of scientific achievements, like pollution of the environment, and so on.

[1] See, *Science and Technology: Tools for Progress. The Report of the President's Task Force on Science Policy,* April 1970.

favourable (in contrast to the payments and trade balance), but increased from $200 million in 1960 to $2,300 million in 1971. However, no one (including prominent economists like Edward F. Denison) could convince the powers that be that this could have been achieved without the highly impressive inputs into R & D. In the past decade, this amount, coming from all the sources of finance, totalled nearly $170,000 million at constant 1958 dollars. [1]

Meanwhile, the US positions in the world economy, far from being fortified, had in fact weakened. The US share of world capitalist exports fell from 17.5 per cent in 1950 to 15.9 per cent in 1970, and of the world capitalist GNP, from 51.4 per cent to 40.6 per cent. Besides, the gap between the US GNP in current and constant (1958) prices increased from $17,000 million in 1960 to $254,000 million in 1970, or from 3 per cent to 26 per cent. [2] Inflation spread to other capitalist countries as well.

Nevertheless, the US market was ever more heavily flooded with radioelectronic, motor and other manufactured products from Japan, the FRG and other countries, whose R & D outlays were only a fraction of those of the United States. The erstwhile US superiority in trade with these countries in technologically intensive products, like electrical and general engineering, chemicals, and in the long term also aircraft and motor manufacture was shaken. [3] From the beginning of the 1970s, the curve of the US trade balance in these industries began to decline most perceptibly vis-à-vis the countries of Western Europe and Japan. In the 1960s and early 1970s, these countries managed to attain much higher rates of labour productivity growth than the United States (although, like the United States, they failed to have this offset the higher cost of labour power).

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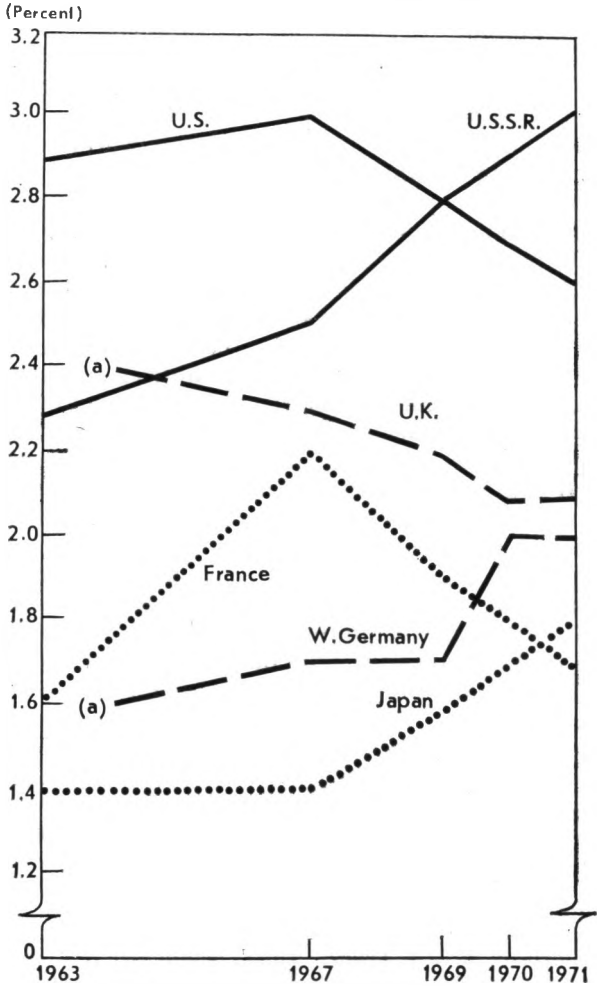
[1] A report by the National Science Board of the United States for 1972 said that while science and technology had an important economic role to play, this was only one component in the intricate matrix factors which determined the country's technical and economic positions (including legal, financial, social and market factors), and that it was hard to establish their exact share (*Science Indicators 1972,* p. 22).

[2] P. G. Peterson, *The United States in the Changing World Economy,* Vol. 2, Washington, 1971.

[3] *Science Indicators 1972,* p. 16.

Figure 1

R and D Expenditures as a Percent of Gross National Product, by Country, 1963-71[1]



(a) 1964

SOURCE: Organisation for Economic Cooperation and Development; National Science Foundation estimates for 1970 and 1971; U.S.S.R. estimates by Robert W. Campbell, Univ. of Indiana

Robert M. Solow and other US economists have long since established the high positive effect of R & D for labour productivity growth. [1] Nevertheless, in the 1960s, labour productivity in the United States grew at a slower pace than it did in Britain, France, the FRG, and especially, Japan (see Fig. 1). This jeopardised the traditional US superiority in this field.

Such facts enhanced the disappointment with science among US ruling circles, who have behind them a long-standing tradition of pragmatism.

The readiness of the legislators to continue increasing R & D appropriations was markedly dampened by the mood of the electorate, which made no secret of its dissatisfaction with the expenditure of government funds on ambitious globalistic programmes, instead of a solution of strident everyday problems. A poll taken by the Opinion Research Corporation at the request of the National Science Board in June 1972 showed the following "system of values" among US voters in the field of science and technology.

Table VII-3 shows that from the US voters' standpoint the most costly scientific and technical programmes —defence and space—were the least worthwhile, with the maximum preference given to the protection of human health and the biosphere, two items on which much less had been spent until then. The same cannot be said about the production of new basic knowledge, which was well down on the voters' "system of values". The response at the "top" was even more unambiguous.

The fiasco of the "strength policy", the growing threat to the US positions in the world economy, the symptoms of the energy and economic crises, all of these induced the federal administration to "tighten up the screws" in US science, and to reappraise its priorities. Characteristically, military programmes alone retained their priority.

Table VII-4 shows that in the past 23 years there has been a sharp drop in the average annual growth rate of R & D funding. In current dollars, it declined to less than one-half, and in constant 1967 dollars, to a fraction of the original figure, and in fact acquired a minus sign.

[1] Robert M. Solow, "Technical Change and the Aggregate Production Function". In: *Review of Economics and Statistics*, Vol. XXXIX, No. 3, August 1957, pp. 312-20.

Table VII-3

In Which of the Areas Listed Would You Most Like (and Least Like) to Have Your Taxes Spent for Science and Technology?

Response	Per cent choosing area	
	Most Like	Least Like
Improving health care	65	1
Reducing and controlling pollution	60	3
Reducing crime	59	2
Finding new methods for preventing and treating drug addiction	51	4
Improving education	41	4
Improving the safety of automobiles	38	5
Developing faster and safer public transportation for travel within and between cities	23	14
Finding better birth control methods	20	18
Discovering new basic knowledge about man and nature	19	15
Weather control and prediction	11	19
Space exploration	11	42
Developing improving weapons	11	30
No opinion	6	13

Note: Multiple answers were allowed.
Source: *Science Indicators 1972*, p. 99.

Having been deprived of a sizable portion of government contracts, the monopolies cut back their research personnel, so that for the first time the supply of research labour was markedly in excess of demand. In 1975, unemlpoyment among scientists and engineers engaged in R & D reached 4.5 per cent in the United States. In 1970, the number of scientists in the natural sciences and engineers employed in industrial R & D dropped to the 1967 level, [1] and in 1975 remained the same. Altogether, from 1969 to 1972, 8 per cent—31,000 of the scientists

[1] *Science Indicators 1972*, p. 48.

Table VII-4

R & D Funding Trends, 1953-1976 (%)
Average Annual Rate of Growth

Year	Current dollars			Constant 1967 dollars		
	Total	Federal	Non-Federal	Total	Federal	Non-Federal
1953-1961	13.7	16.3	10.1	11.3	13.9	7.8
1961-1967	8.4	7.7	9.6	6.3	5.6	7.5
1967-1976	5.7	3.8	8.3	—0.3	—2.2	2.1

Source: National Patterns of R & D Resources. Funds & Manpower in the United States 1953-1976, NSF 76-304, Washington, 1976, p. 2.

and engineers at industrial laboratories (in terms of full employment)—lost their jobs. [1]

We find a similar tendency in Britain, where it was being said that the progress of society was not due mainly to science, whose role and merits had been greatly exaggerated, but to consumer demand and the inventions which went to meet it. The steam engine and the internal combustion engine had been invented not by scientists but by practitioners. The role of pure science was to be most radically reappraised: young people who went into it were turning their backs on the need to meet society's vital requirements.

Professor Price, while being a British subject, had been a member of US President's Science Advisory Committee for two years, and he testified that there was a growth in the United States of downright anti-scientific and mystical attitudes, which he believed stemmed from the sharp slowdown in the growth of science. But he saw this chiefly as confirmation of his own science growth model and its forthcoming saturation, which made for the switch from exponential to logistic growth. Accordingly, Price believed that the current decline in scientific

[1] *National Patterns of R & D Resources. Funds & Manpower in the United States 1955-1973*, p. 14. Private industry employment of scientists and engineers in 1975 shows 5-year decline (NSF 77-312, p. 1).

activity was inevitable and natural, being connected with the inner logic of science growth rather than with any social factors. Assuming his model to be universal, he has predicted a similarly inevitable decline in scientific activity—together with the attendant growth of anti-scientific attitudes—in other countries, among them the USSR, following the United States.

But what is the mechanism of saturation?

Professor Price, who has studied the uneven distribution of scientific activity across the world, does not in any sense identify saturation with the saturation of the whole of human society with scientific knowledge. He is quite right in anticipating, in particular, tremendous growth of scientific activity in the developing countries, although here one can hardly accept his idea that the "superdeveloped" countries, like the USA and the USSR, are to be relegated to positions more in accord with the size of their population. I think that the spread of universal scientific and technical culture, which Price has considered, will deprive such antitheses of their present importance.

But the "saturation" of the industrialised countries with science is itself highly relative, because there is a great difference between the scientific and technical level in the various regions and industries. In this context, let us recall, for instance, the 1965 US Act on technical aid to the States in order to level out the conditions of scientific and technical progress in the country. The differences in these conditions are even more pronounced among the industries, for the saturation of the aerospace, radioelectronics, chemicals and engineering industries with science is out of all proportion to the availability of science in the food, woodworking and similar other industries.

In Price's model, saturation implies the "self-saturation" of science with the waste of its own growth, which grinds to a halt because of "self-intoxication". Price says this is due to the fact that the less valuable factors of science have always tended to grow faster than the more valuable ones: expenditures have grown faster than the number of personnel, and the number of personnel, faster than productivity. The relationship between the growth of expenditures and personnel is confirmed by science

statistics. Thus, from 1953 to 1973, US R & D expenditures (in current prices, that is, not discounted for inflation) increased roughly 5.8-fold, while the number of scientists and engineers engaged in R & D increased roughly 2.2-fold. [1]

From 1950 to 1973, expenditures on science in the USSR multiplied over 10-fold, and the number of research personnel, 7-fold. [2] But the faster growth of expenditures is apparently due to the expanded construction of science buildings and installations and the growing use of ever more costly scientific equipment, which since the second half of the 1950s has included powerful atomic accelerators, oceanographic vessels, radio telescopes, electron microscopes and, finally, space rockets and stations. This item of expenditures can hardly be designated as "low-value" not only from the standpoint of scientific development, but also of the improvement of production; one need merely think of electronic computers, nuclear hardware, space communications and information, meteorology and medicine.

Price's assertion about the relationship between the growth of personnel and scientific output is even less incontestable. Thus, from 1925 to 1962, the number of physicists, who were, say, members of the American Society for Physics, tended to double every 11 years, in accordance with a corrected exponential, just as did the number of newly discovered elementary particles, which from 1897 to 1962 also doubled every 11 years. [3] Indeed, any assertion concerning the growth of science productivity may well be invalidated by the indefinite criterion of such productivity. After all, no adequately reliable yardstick is provided by the number of published scientific papers, or the number of references to the works of authors in the papers of others. [4]

Price further claims that in the conditions of saturation, countries with planned economies are trying to make science and technology serve the state and yield the greatest possible returns, with science here being re-

[1] *National Patterns of R & D Resources. Funds & Manpower in the United States 1953-1974,* pp. 28, 8.
[2] *The Economy of the USSR in 1973,* pp. 129, 726.
[3] *American Scientist,* Vol. 50, No. 1, March 1962, pp. 8-9, 11.
[4] *Science Indicators 1972,* pp. 8, 9.

garded as a bridge leading to technology, instead of being a factor in its own right. In a number of cases, this leads to lower labour productivity and sometimes to tangible losses. Moreover, Price believes, such a policy may well induce slower scientific and technical development.

One will easily see that this approach is artificial. After all, even according to Price, the "countries with planned economies", that is, mainly the socialist countries, are still to follow the United States in reaching saturation, which is highly dubious even in that country. That is why, in constructing their science policy in this hypothetical (and very unlikely) situation, Price simply extrapolates to them the pragmatic approach now prevailing in the US Congress. But linear extrapolation is a highly unreliable method of prognostication, especially when it cuts across the actual tendencies of development, as it does in this case.

The 25th Congress of the CPSU, which laid down the main lines of Soviet science policy, emphasised, among other things, the tasks in further advancing basic research, vigorous extension of the whole front of the social and natural sciences, and the leading role of the USSR Academy of Sciences, which continues to be the basis for accelerated scientific and technical progress and its rising effectiveness. Consequently, the hypothetical utilitarianism of the "countries with planned economies" in the equally hypothetical conditions of saturation cannot in any sense "act as a main retarding factor", that is, as some kind of brake-shoe of saturation.

What then remains of the saturation mechanism in general? It is hardly possible seriously to insist on society's saturation with science either in the developing countries or in the developed socialist countries. Even for the United States, to say nothing of the other capitalist countries, saturation is a term which fails to show the whole complexity of the actual processes slowing down scientific progress and the forces behind them. It is hard to understand anything in the mechanism behind the growth of modern science without analysing the concrete social conditions in which it has to develop. This is well brought out—even if in a negative sense—by Prof. Price's hypothesis concerning science policy in the socialist countries under saturation. Equally unconvinc-

ing, and for the same reason, is the idea of the "self-saturation" of science, with its vulnerable "system of values" for the individual science-growth factors and neglect of the fact that each of these is socially mediated, and also of the dialectics of their development. Thus, the automation of research work, considered above, will not only help to overcome the "information crisis" and to develop scientific self-organisation, but also markedly to alter the balance between financial and personnel resources at the "input" and scientific productivity at the "output".

Already, the cost of some research programmes in practice boils down to the cost of the required number of machine-hours. But the cost of the work performed per machine-hour has a clear tendency to decline with the improvement and lower cost of electronic computers and services. In this context, Japanese estimates of computer efficiency are highly revealing (see Table VII-5).

Table VII-5

Comparative Data on Aircraft Strength in Air Drag
(About 8 million Computing Operations)

Facility used to process data	Time of computation	Cost of computation (yen)
Abacus	15 years	*
Calculator	80 weeks	*
First generation computer		
IBM-701	2 mins	1,550
IBM-704	30 secs	860
IBM-709	25 secs	700
Second generation computer		
IBM-7090	5 secs	180
Third generation computer	0.7 secs	20

* Cost prohibitive.

Source: *Computer Hakusyo*, p. 26. (Y. A. Savinov, *Capitalism and New Technology. Electronic Computers: Problems in Manufacture and Use*, Moscow, 1974, p. 254, in Russian.)

Meanwhile, it is not the number but the quality of the personnel that determines the advance of science. Morale

and dedication are the touchstones of quality, alongside the formal indicators of education, skill standards, experience, etc. Disappointment in science among the scientists themselves is surely an alarming symptom of a slump if not of a decline, in science in the United States and some other capitalist countries. But this is not a worldwide trend. [1]

That a mood of historical optimism prevails among scientists in the USSR will be seen from their replies to the *Literaturnaya Gazeta* poll, entitled "The 20th Century: Science and Society", which was taken in 1971-1973. The outstanding Soviet scientist, Academician A. Alexandrov, wrote: "The point is that in its development science has approached the examination of problems whose solution results in by far too important consequences. Perhaps the most convincing example of this is a scientific work like Marx's *Capital,* whose importance needs hardly to be explained. Science will probably maintain its important place in society, although the character of its development (and the development of science is only a part of society's development) will change." According to A. Sadykov, President of the Uzbek Academy of Sciences and Corresponding Member of the USSR Academy of Sciences, "it is totally inconceivable to assume that the progress of society, the progress of science can stop for any period of time, however short, or that the human mind can sink into a state of anabiosis". Academician V. Ginzburg echoes this idea: "In future, the role of science is bound to grow." Academician V. Engelgardt writes: "Science has become the key productive force. I should even say that it has become... a source of growth for all of society's productive forces in general. That is why, I believe, science is the main factor both in our present existence and in mankind's forthcoming progress." Academician E. Andronikashvili of the Georgian Academy of Sciences suggests that "the development of

[1] Let us recall that more than 90 per cent of the nearly 4,000 researchers in the Soviet Union who were polled by *Literaturnaya Gazeta* emphasised above all an inducement like satisfaction from the process of cognition and creativity itself. Let us note here the highly representative character of the file of questionnaires obtained (*Literaturnaya Gazeta* No. 34, August 18, 1971).

science is in a sense described by the chain reaction equation.... Of course, the mounting pace of scientific and technical progress could result in a situation in which men and nature will fail to adapt themselves to the new conditions of being that the rapid development of science and technology will impose on them. That is when the need will arise for 'governing pivots'. Socialist society will easily find a way out of the critical situation.... But capitalist society, with its wild and unbridled competition could lose control over the process: scientific and technical progress could become ungovernable."

These apprehensions are also shared by other scientists, including Nobel Prize Winner Professor R. Norrish. Science cannot exist simply on its own. It must develop. And this requires living bonds and dynamic interaction with society. Prof. F. Crick and his associate in the discovery of the DNA structure, Prof. M. Wilkins, justly note that science has acquired an important role in the life of mankind chiefly because of the possibilities of making practical use of its results, and that this role of science is bound to grow, rather than diminish in the future.

Consequently, Prof. Price's saturation of science is just as groundless as similar ideas which were repeatedly put forward in the past. Two centuries ago, the German scientist and thinker Georg Christoph Lichtenberg wrote: "It is highly shortsighted to draw the conclusion that science is in decline from the contemporary state of learning, when the ratio of usefulness, profoundness and dalliance is 1 to 3 to 5.[1] After all, this zigzag is by and large only becoming a persistent trend, and it is still too early to judge whether it will lead to upswing or decline.... These are essentially imperceptible bends in a big line and only at close range does it seem as though it was turning back."[2]

This observation by the perspicacious German thinker remains true to this day, as will be seen from the data on the share of R & D expenditures in the GNP in the leading countries of the world over the past few years

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[1] Cf.: productivity, personnel and expenditures on science as estimated by Price.

[2] *Georg Christoph Lichtenbergs Aphorismen,* Hrsg. von A. Leitzmann, 2. Heft: 1772-1775, S. 132.

(see Fig. 1).[1] Together with the dwindling of the share in the GNP in the USA, Britain and France, we find it increasing in the USSR, and also on a more modest scale, in the FRG and Japan.

It will be easily seen that on the whole the growing share of R & D expenditures in the GNP tends to follow the pattern of alternate economic booms and busts, although they may not coincide in time. Price assumes that the current economic crisis follows in the wake of a slump in science and technology, and that the retarding in the growth of science is a cause, and not the effect of the economic crisis. Actually, the causal nexus between science and the economy is much more complicated and little known; thus, while the multiplicatory effect of science growth on the economy was established in the late 1950s, the reverse correlation between any slow-down in science growth and the decline in economic activity has yet to be established. This has been an important factor behind the present disappointment in science among ruling circles, and not only in the United States, but in other capitalist countries as well, so causing cut-backs in R & D appropriations. The prominent US economist R. Solow has contested the idea of research as a factor behind economic growth and has made the following assertion: "No positive correlation whatsoever is evidenced between the national rate of economic growth and the national level of R & D expenditures.... R & D ... can itself be a drag upon, as well as a stimulus to, growth, and ... the detriment to growth [economic—*Y. Sh.*] implicit in R & D itself may not have been artificially offset by its benefits."[2]

The growth curve of science expenditures as a percentage of the gross social product in the USSR is sufficiently characteristic (see Fig. 1). From 1963 to 1967, it is on a smooth upgrade, but in the following period

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[1] This relative, "weighted" indicator is more reliable than absolute figures, because it does not require the computation of a deflator, since inflation has equally affected both R & D expenditures and the GNP.

[2] Robert A. Solow, "Gearing Military R & D to Economic Growth". In: *Harvard Business Review*, November-December 1962, p. 50.

the upswing is much steeper, showing greater consistency than similar trends for the United States, France and Britain.

But for all the distinctions stemming from the socio-economic specifics of the two world systems, these curves are dynamically of the same type in the sense that they do not reflect either exponential or logistic but *pulsating* growth in science. The period of pulsation comes to four-five years: every few years, on average, science growth tends to stop for one to three years relative to economic activity, only to build up for a fresh upswing. These pauses are apparently not accidental. They are necessary to give society, and its production apparatus in the first place, the time to digest the scientific and technical results they have received. [1] Periodic pauses are characteristic both for financing and for the development of science itself, and rule out any absolute saturation of the living organism.

Back in 1929, the Soviet scholar T. J. Rainoff published an original work which characterised five-year cycle changes in the number of scientific discoveries in Britain, France and Germany from 1626 to 1900. He drew the conclusion that the number tended alternatively to grow and diminish from year to year to a greater or lesser extent, and that these frequent fluctuations occurred about an exponential curve showing the growth of the total number of discoveries. Comparing these fluctuations with the fluctuations of the economy, Rainoff noted a sufficiently satisfactory correspondence between them (for instance, in Britain). [2]

But in contrast to material food, spiritual nourishment like scientific knowledge cannot simply lie there, awaiting its turn. Knowledge cannot be put in cold storage, but has to be constantly developed and renewed. The growth of science cannot be suspended without risk of irreparable harm to its development. Nor does it, in fact,

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[1] Mathematically, these pulsations are analogous to those which arise in the interaction between two sinusoidal waves with equal amplitudes and slightly different frequencies.

[2] T. J. Rainoff, "Wave-like Fluctuations of Creative Productivity in the Development of West-European Physics in the Eighteenth and Nineteenth Centuries", *Isis* No. 38, 1929, p. 306.

stop. Above I mentioned the leading role which it has in ensuring continuity and constancy of scientific and technical progress in the USSR. But in the United States as well, the basic research budget multiplied 9-fold in the 20 years between 1953 and 1973, when it reached $4,500 million, [1] and $4,800 million in 1976 (in current prices). The federal administration has increased its commitments on basic research from 1972 to 1976 to $2,500-3,200 million in current prices, or to $2,400-2,500 million in constant prices.

The budget of the National Science Foundation, the central US agency in basic research, is estimated to have risen between 1974 and 1975 by 11.5 per cent and between 1975 and 1976 by 9.3 per cent to $678 million.

It is true that this increase is earmarked not so much for "pure science" as for its application (for instance, in energy, in combating natural disasters, in ecology, and so on). [2]

A tendency to continued advance is also revealed by a "weighted" indicator like the scientific personnel as a percentage of the total population (see Fig. 2). [3] These curves for the USSR and for the United States from 1963 to 1967 rise upward, more steeply in the former and less so in the latter. In that period, the proportion of scientific personnel in the USSR increased from 19 to 25 per 10,000 population, later on substantially exceeding the same indicator for the United States, where the increase has been insignificant, from 25 to 26 per 10,000 population, and where it began markedly to decline from 1969 on. Despite the attainment of the impressive figure of 37 per 10,000 population in 1971, and despite the rapid growth rates, the Soviet economy's demand for scientific

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[1] *National Patterns of R & D Resources. Funds & Manpower in the United States 1953-1973,* p. 6.

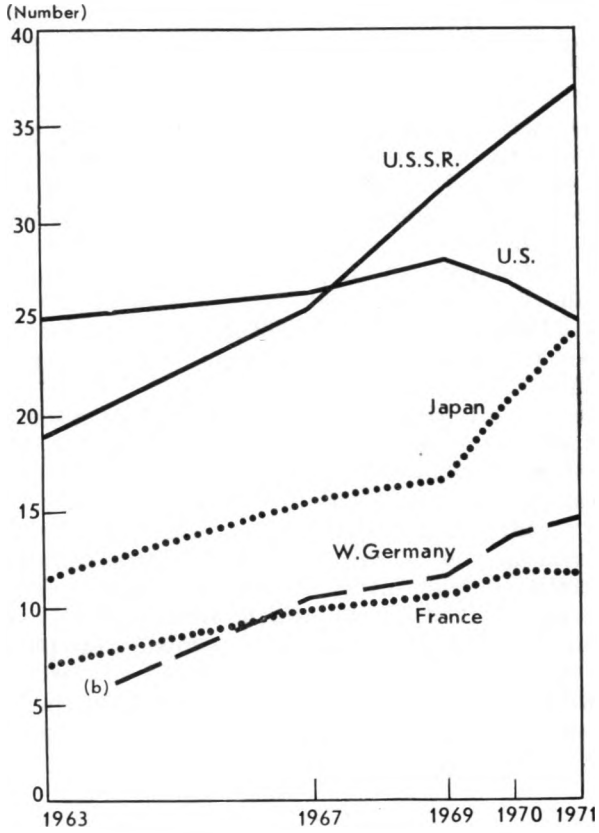
[2] *Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1974, 1975 and 1976,* NSF 75-384, Vol. XXIV, p. 6.

[3] Here the use of "weighted", that is, relative magnitudes is also preferable to absolute figures, because it facilitates quantitative comparisons of "research personnel" in the USSR and "scientists and engineers engaged in R & D" in the United States and other countries (the saturation of whose economy with scientific personnel is fully comparable).

personnel is still a long way from saturation, when science has been developing into the leading factor of the productive forces and the scientific transformation of production as a whole.

Figure 2

Scientists and Engineers[a] Engaged in R and D per 10,000 Population, by Country, 1963-71[1]



(a) includes all scientists and engineers (full-time-equivalent basis).
(b) 1964

SOURCE: Organisation for Economic Cooperation and Development; National Science Foundation estimates for 1970 and 1971; U.S.S.R. estimates by Robert W. Campbell, Univ. of Indiana

In the United States, where tens of thousands of scientists and engineers have lost their jobs, and where there have been heavy cuts in programmes for training new scientific personnel, the National Science Foundation has forecast a growth of demand for such personnel, especially in the nonresearch spheres of activity. [1]

According to estimates for 1975, about 531,000 scientists and engineers in the United States were engaged in R & D (in terms of full employment) in every sector of the economy. This is roughly one-third of all the working scientists and engineers, being slightly less than the 1960-1970 figure (36 per cent). Between 1954 and 1969, the number of scientists and engineers engaged in R & D increased on average by 5.9 per cent a year, or over three times faster than total employment in the civilian sector, and 12 per cent faster than the total number of professional technical workers. But from 1969 to 1973, the number of scientists and engineers in R & D declined at 0.3 per cent a year. Only between 1973 and 1975, did it go up by 9,400, but the 1975 peak was still nearly 30,000 less than the 1969 figure.[2] This does not in any sense meet the requirements of the national economy.

Consequently, it is not saturation but pulsation which characterises the growth of modern science, and this has been exemplified by the Soviet Union, the United States and various other industrialised countries. In the light of the actual distribution of scientific activity throughout the world in the second half of the 20th century and the extremely high international centralisation and concentration of R & D, of which something like three-quarters are concentrated in these countries, the pulsating model of science growth may be accepted as a worldwide one, with socio-economic conditions, however, being the determinant factor of its development, now and in the future.

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[1] See, *1969 & 1980. Science & Engineering Doctorate Supply & Utilisation, May 1971,* NSF 71-20, Washington, 1971.

[2] *National Patterns of R & D Resources. Funds & Manpower in the United States 1953-1974,* p. 8.

Chapter Eight

Science Policy Strategy

The complex processes connected with the scientific and technical revolution are objective, because they unfold above all in the sphere of the productive forces. But their course and results are not spontaneous, not independent of the will and consciousness of men. The contradictions inherent in these processes and the premises for their resolution are directly dependent on social conditions, on the pattern of the political forces shaping science policy.

Dynamic Goal and Character of Strategy

Let us note that the more fundamental a discovery or invention, the deeper or broader, and the more indefinite is its effect in quantitative terms. Whether we consider the discovery of the law of the conservation of energy or Mendeleyev's periodic law, the theory of relativity or the mechanism of biosynthesis, or finally, the very principle of indefiniteness, the effect has in every case turned out to be indefinite precisely because, and to the extent of its boundless breadth, of its immensity. This is also true for what could appear to be narrower and more concrete technical inventions. Thus, the effect from the invention of the airplane is very much broader than any technico-economic indicators of development in modern aviation could suggest, however impressive these may be.

The effect from the invention of television is expressed not so much in the rapid growth of the electronics industry, or even in the saturation of the world with

1,000 million TV sets, as in the deep-going even if elusive socio-psychological changes, in the use of TV companies as an efficient instrument in political struggle, the development of the specific TV genres of art, and so on. For my part, I have dealt with the TV model of scientific and technical progress, which, I think, presents its main lines fairly accurately.

The development of the skill to forecast first the immediate and then ever more remote consequences of one's action has apparently been pivotal to the process of cephalisation, the steady perfection of man's brain and the enhancement of his intellectual power. His elaboration of the most appropriate strategy of active adaptation to his habitat and its transformation to provide for his own needs at a certain stage led to the emergence and development of science. Nowadays, the development of science has itself reached a stage at which it requires the elaboration of a special strategy as the starting point for science policy.

Let us take strategy to be a plan of action designed for the most efficient attainment (that is, attainment within the shortest period with the established inputs or within the established period with the lowest inputs) of the general goal through the correct selection of lines and the concentration along these of the crucial forces and funds in accordance with the "goals tree" priorities.

The share of investments in the future, as compared with investments in the present, is one of the key characteristics of the level of strategic thinking, whether it is oriented upon the attainment of the naively mystical goals of the past or the scientific goals of the present.

Indeed, it is the broad social rather than the narrower technico-economic effect that predetermines the choice of general goal in scientific and technical (as, of course, in social) progress. This goal should not be something that is frozen once and for all, but a highly dynamic and developing system, capable of providing the most efficient resolution of all the foreseeable and conceivable contradictions in future development.

To achieve this, the general goal must be in accord with the general tendency of social development.

The general tendency of the past century was the transformation of science, as Marx noted, into an im-

mediate productive force. Marx suggested that this transformation should be measured by the extent to which "the conditions of the social vital process itself are subject to the control of the universal intellect and are transformed in accordance with it; the extent to which the social productive forces have been created not only in the form of knowledge, but also as immediate organs of social practice, of the real vital process". [1] This tendency is now being realised through the scientific and technical revolution, through the cybernetic automation of production based on the revolution in information and communications.

These tendencies stem from each other, constituting a coherent system, a general tendency. The strategic scheme rests above all on the normative prognosis, which determines the concrete subgoals of the present in the light of the general goal of the future. But the authenticity of normative prognostication, and so also of the strategic scheme, depends on the extent to which it coincides with the search prognosis, with the extrapolation of the tendencies of development in the past through the present into the future. [2] In this case, the general tendency—and this is highly important—coincides with the normative general goal of science development strategy, namely realisation of the universal (integral) intellect, which Marx had envisaged. To the extent to which science becomes an immediate productive force, the Integral Intellect will assume the functions of controlling the very conditions of the social vital process and their corresponding transformation. That is the only kind of system that will meet the requirements made on the normative general goal, which is to serve as an efficient instrument in overcoming the conceivable contradictions in future development.

Nowadays, as I have already said, science and organisation, operating as a single whole, as scientific organisation, integrating socially organised science and scientific organisation of social production, have the leading role to play in remodelling social conditions in accordance with the requirements of scientific reason in the sphere

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[1] Karl Marx, *Grundrisse der Kritik der politischen Ökonomie (Rohentwurf) 1857-1858*, S. 594.

[2] Erich Jantsch, *Technological Forecasting in Perspective.*

of the productive forces. That is why the most important and crucial form of "investments in the future" is, on the one hand, the utmost development of science and scientific education, and on the other, of information and control systems, the basis of scientific self-organisation in the future.

These are the primary subgoals on whose attainment the crucial forces and funds should today be concentrated so as ultimately to attain the general goal in the most efficient way and to realise the strategic scheme.

By definition, strategy is a vector. Its principal vector characteristics are single-mindedness and purposefulness, the distinction between the two being that the latter gives more exact expression to the active character of strategy, and the former to its stable and homeostatic character. Single-mindedness is the steady and balanced advance towards the general goal, consistent realisation of the strategic scheme, and maintenance of the right orientation, whatever the complications and forced manoeuvring. Purposefulness is the active drive, the concentration of efforts to attain not only the general goal but also all the subgoals at every level (all the tiers of the "goals tree"), starting with the most proximate and immediate ones.

While single-mindedness gives strategy its orientation, purposefulness invests it with dynamism. Orientation without dynamism is just as ineffective as the other way round, for the two are not antithetical, but complementary to each other. Overemphasis on the attainment of the immediate most proximate goals may result in the loss of orientation upon the general goal (although its attainment is not at all promoted by neglect of urgent immediate tasks either). The right strategy is based on the maintenance of a definite balance between the efforts aimed to attain the general goal and the efforts geared to the solution of the most proximate problems.

Nowadays, when the development of science is inseparably linked with social development, science strategy can exist as a key component of the strategy of scientific organisation. Given the indefiniteness inherent in scientific activity as such, this strategy has the task above all of determining the most rational balance between the efforts going into the present and into the future.

Now and again there is a debate on whether the scientific and technical revolution should be accelerated or slowed down, leaving the impression that its parameters are something like those of the car speedometer, where all one has to do is to press or release the accelerator.

Actually, this is an objective process in the development of the productive forces which has an organic and inherent tendency towards spontaneous self-regulation. It is not so easy to regulate this process consciously or to subject it to scientific organisation. We still have a long way to go before we can manage the process effectively. Today it would be a really good thing for us to understand how it "works" and to identify the conditions and factors which influence its course.

Feedback is a characteristic of the current scientific and technical revolution as a self-regulating process.[1] The feedback between society and science is necessary for providing sensitive signals of any equilibrium disruptions, so making its rapid re-establishment possible.

The need (and possibility) of this kind of feedback makes it necessary to have a special science policy strategy. After all, we have here a complicated and contradictory process, which cannot be left to run its own course. While the scientific and technical revolution, on the

[1] The existence of feedback will be seen from demographic data like the statistics of marriage and divorce. The mobility of the population tends to increase with its growth, so leading to intensified contacts between men and women on an unprecedented scale. This "automatically" results in a growth in the number of divorces relative to the number of marriages where the intensity of contacts reaches a maximum. But the growth in the number of divorces causing a decline in the birth rate must sooner or later lead to a slow-down in population growth. This, for its part, will cause a decline in the intensity of contacts and, consequently, in the number of divorces. With time, within a certain period, this course of events should provide the impetus for a new cycle, which gives the whole demographic process a pulsating character. Consequently, some sort of self-retardation periodically occurs in the growth of the population. Indeed, it can already be observed in the industrialised countries (like the periodic pulsation in the growth of scientific activity and science-transformed production [see Chapter Seven]). According to the latest estimates, a reduction in the growth of the total population is expected to occur in the first half of the 21st century, when it reaches 11,000 million (*World Economics and International Relations* No. 8, 1975, p. 107).

one hand, tends to expose what could be called the sores on the social body of mankind (aggravating, for instance, the problem of nutrition), on the other, it itself creates the wherewithal for healing these sores (notably, for solving the nutrition problem even under a "demographic explosion").[1] Indeed, strategy is designed to envisage the single-minded and purposeful transformation of this potentiality into reality. For the socialist countries this means above all using the advantages of their social system for the fullest realisation of the potentialities of the scientific and technical revolution.

However, with the existence of the two different social systems, the scientific and technical revolution initially tends rather to aggravate the contradictions of social development, including demographic, ecological and other problems. As each is individually intensified, all tend to complexify each other. This process, as Prof. J. W. Forrester has emphasised in his book, *World Dynamics*, does indeed tend to grow exponentially, so that his pessimism is, in a sense, "a well-informed optimism". However, the extent of his information also turns out to be inadequate. "The limits of growth" cannot be accepted as the limits for the development of society, because development does not stop there. Every action produces an equal and opposite reaction: the scientific and technical revolution is entering upon its next stage, the stage in which the premises mature for the resolution of the contradictions. These premises are fully realised in an atmosphere of unhampered and developing international cooperation and ultimately of the triumph of communist social relations.

Such is the real dynamics of the world. It follows from a scientific analysis of the tendencies, taking account of the possibility of actually resolving the contradictions of development with the aid of a science organisation strategy.

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[1] Provision of food for the population in the developing countries on the basis of the "green revolution" is an important step in creating the possibilities of subjecting their demographic dynamics to the same laws of pulsation and periodic self-retardation which now operate in the industrialised countries. But realisation of these potentialities entirely depends on the actual socio-political conditions.

The choice of general goal lies at the basis of the most important and proper function of strategy, which is selection of the main lines of development in science and technology. The distribution of resources and efforts between the present and the future depends on this.

For the new five-year plan in the USSR, concrete programmes have been elaborated for the first time "to resolve the key scientific and technical problems which determine the whole complex of necessary work, including measures for the introduction of new machinery in industry. The targets they envisage must be backed up with resources, and tied in with the plans for production, capital construction and material and technical supply." [1]

System of Main Line Selection

The selection of the main lines of scientific and technical progress should rest on a complex of clear-cut and reliable criteria.

These criteria are sufficiently reliable only if they constitute a system. This means that in the aggregate these criteria should themselves constitute a definite system, for only then will they ensure a systems approach to the tasks of selection.

The character and the high and ever growing pace of scientific and technical progress require that the selection of the main scientific lines should be prognostic. In the USSR, the strategy of scientific quest is determined by the USSR Academy of Sciences, which brings out the most promising lines and forms of research required by society, and pools the efforts of the country's scientists. The systems approach on the basis of the selection criteria adopted should be similar. The application of criteria in the process of selection should develop dialectically from the broader to a narrower system.

The *system of relationships between society and nature* is apparently the broadest possible system from which the criteria of selecting the main lines in science

[1] *Documents and Resolutions. XXVth Congress of the CPSU*, p. 136.

should stem. This system is in a definite equilibrium, which now faces the threat of irreversible disruption.

The development of the noosphere on the globe still lags behind the rapid growth of the technosphere, which eludes the control of scientific reason and tends to upset the equilibrium of many processes in the Earth's biosphere that had taken shape over millions of years and that is very hard to reconstitute. This applies to the whole range of negative phenomena arising from the pollution and damage of the natural environment: air, soil, water, flora and fauna.

Underestimation of this criterion (maintenance of equilibrium between science and nature) has already resulted in a grave distortion of the meaning and purposes of scientific and technical progress. In the absence of any sufficiently comprehensive systems approach, this poses the threat of ecological crisis.

Scientists from various countries, among them J. W. Forrester, D. L. Meadows and D. H. Meadows of the United States, the prognosticators of the Club of Rome, and a group of influential British ecologists, suggest that this crisis is inadvertent and have stressed its disastrous consequences. In their well-argumented manifesto, *A Blueprint for Survival*, published in early 1972, they say: "An examination of the relevant information available has impressed upon us the extreme gravity of the global situation today. For, if current trends are allowed to persist, the break-down of society and the irreversible disruption of the life-support systems on this planet, possibly by the end of the century, certainly within the lifetimes of our children, are inevitable. Governments, and ours is no exception, are either refusing to face the relevant facts, or are briefing their scientists in such a way that their seriousness is played down. Whatever are the reasons, no corrective measures of any consequence are being undertaken.... Industrial man in the world today is like a bull in a china shop, with the single difference that a bull with half the information about the properties of china as we have about those of ecosystems would probably try and adapt its behaviour to its environment rather than the reverse. By contrast, *Homo sapiens industrialis* is determined that the china shop should adapt to him, and has therefore set himself the

goal of reducing it to rubble in the shortest possible time." [1]

While recognising the gravity of the threat to the natural environment posed by the headlong advance of industrialisation, especially where the laws of capitalist competition reign supreme, one cannot accept the suggestion that the situation is hopeless.

Thus, in the USSR extensive measures have been taken to protect nature, where the socialist property in land, its subsoil, waters and forests allows the state to plan economic activity and so erect a reliable barrier in the way of any disruptions of the ecological balance. CPSU congresses have given much attention to the rational use of natural resources, and in accordance with their decisions, the five-year plans for the USSR's economic development contain the relevant provisions. The legal rules in this area are laid down by the recently adopted Fundamentals of Land and the Fundamentals of Water Legislation, the Fundamentals of the Legislation of the USSR and the Union Republics on Public Health, and the corresponding laws and codes in the Union republics.

A decree "On Measures for the Further Improvement of Nature Protection and the Rational Use of Natural Resources" says: "Protection of nature and the rational use of natural resources under the rapid development of industry, transport and agriculture, advance of the scientific and technical revolution, and growth of the Soviet people's diverse material and cultural requirements pose a key problem for the whole state on whose solution depend the successful fulfilment of economic plans and the well-being of the present and future generations. Solution of this problem in socialist society is closely bound up with the protection of the health of the population, and provision to Soviet people of the necessary conditions for fruitful work and leisure.... Rational use, conservation and reproduction of natural resources, and regard for nature are a component part of the programme for building communism in the USSR." Important measures in nature protection are also envisaged in the Five-Year Plan for the USSR's Economic Development for 1976-

[1] *Ecologist*, Vol. 2, No. 1, January 1972, pp. 1, 4.

1980. At the same time, there is emphasis in this important matter on the broadest possible international scientific and technical cooperation, with countries like the United States, Canada, the FRG, France and Japan.

The UNESCO report considers the future relationships between society and nature and aptly designates these as a "new symbiosis", under which our attitude to our industrial network and especially to our cybernetic systems tends gradually to be transformed into a more intimate and organic interdependence. Together with long-distance monitoring, control of the Earth and the potential possibilities of controlling the environment by means of artificial satellites they imply the spread of symbiosis to the whole ecology of the globe. The report emphasises the role of artificial Earth satellites in maintaining the ecological balance, for these are, in the true sense of the word, primary ecological instruments of the future by means of which we could adapt our activity to the biosphere more harmoniously. At the beginning of 1973, the United States had 302 and the USSR 102 artificial Earth satellites in orbit. A satellite equipped with monitoring devices and electronic computers will produce maps of regional resources, compare these with requirements and recommend a regimen of optimal control in using these. [1]

Solution of the tasks facing a given social system in its relationship with other systems is another criterion for selecting the main lines in science within the system hierarchy. In the modern world, with its different social systems, this applies above all to the relations between socialism and capitalism. This criterion may relate both to military-political and to ideological, external economic and other aspects of these relations. On the basis of this criterion, the government of a given country determines the character and specifics of development of its military policy and also of its policy in science, technology, culture and other spheres. The USSR's policy is aimed at the utmost development of peaceful relations and cooperation with all countries, and this is determined by the substance of the socialist system. USSR Foreign Minister A. A. Gromyko stated: "In the interests of peace, we are

[1] See, *Science and Human Needs, UNESCO,* Paris, 1974.

prepared to cooperate, and do cooperate with all states prepared to do so. In international policy, it is necessary constantly to reckon with the diverse problems arising from scientific and technical progress, and with the demands which it has been increasingly making on international cooperation. This applies to the area of economic, scientific and technical ties, which are filled with an ever richer content. This applies directly to the new areas of the activity of states, notably, outer space."

This also includes the development of the international division of labour in science and technology. Because many modern scientific and technical programmes (like those in space exploration) are highly complicated and costly, most countries cannot afford them. Let us recall that a large atomic accelerator costs hundreds of millions of dollars and requires high-precision equipment, and—the main thing—exceptionally skilled specialists. That is why such projects are ever more often implemented on an international basis. Thus, at the large Serpukhov proton synchrotron near Moscow, scientists and engineers from France, the International Atomic Energy Agency and the USSR have been working together in operating Mirabelle, the French-made bubble chamber. Even before this, an international team of scientists had taken shape at the Joint Nuclear Research Institute at Dubna.

The so-called technological balance of payments, which is the balance in trade involving scientific and technical information, has an ever more important role to play in international economic research. Over a long period, the United States has had the largest surplus in this balance, but in the past few years the situation has been changing.[1] In 1960, the USSR was third in the number of patent applications, and by 1964 had forged ahead of the FRG, to first place. Japan, which in 1960 ranked sixth, moved ahead to second place in 1971. The record scale of the purchases of ready-made scientific and technical know-how from other countries has done much to raise world prices for patents and licences.

Following the crisis of the world patent system, which by the mid-1960s had been clogged with unexamined patent claims, a treaty on cooperation within the framework

[1] *Science Indicators 1972,* p. 16.

of a single world patent centre was signed. Such a centre was set up in Vienna in May 1972 with the technical assistance of Siemens of the FRG. In September of that year the CMEA countries decided to join, putting at its disposal nearly 30,000 patent information units (on an equivalent basis). The Soviet Union is a world leader in the number of claims filed for inventions (in 1972 it was first with 132,406), in the number of issued author's certificates (second place in 1973 with nearly 50,000), and is ahead of the developed capitalist countries in the number of inventions applied every year (up to 10,000). But it is still behind in the number of researchers taking part in inventive activity, in the ratio of licences to inventions, in earnings from the sale of licences, and in the share of foreign claims for inventions. [1]

Maintenance of equilibrium within the given social system is the next criterion, which covers both social and internal economic aspects. Much importance attaches here to the balance between society's requirements in scientific and technical progress and the availability of real resources, which include not only financial and material resources but—ever more importantly—personnel and the necessary technical skills. Much has been written on this matter, and with good reason. In the light of this criterion, it appears to be quite right to draw a distinction between effectiveness and profitability in science. Indeed, scientific activity may be quite effective while not being profitable from the standpoint of society, if for some reason it is unable to make use of scientific ideas. But there is another and more long-range evaluation of the indirect, but equally important aspects of the effect obtained, namely, the social effect whose importance does not lie in the quantitatively determined economic benefit, but in the extensive qualitative changes ranging over the most diverse spheres of social life. It is a consideration of all these circumstances that should help to strike the necessary balance between society's potentialities and the needs (and potentialities) of science. Here, one must reckon with the growing role of science within the infrastructure of modern production.

[1] V. A. Obukhov, *Comparison of Statistical Indicators in the Development of Inventions in Some Countries*, Moscow, 1974 (in Russian).

"Infrastructure" is a conception which is increasingly important in present-day economics under the scientific and technical revolution. The economic infrastructure is a kind of substructure of social production on which its normal functioning increasingly depends. The scope of this conception has been steadily growing under the impact of changes in science and technology. [1] While neither the content nor the scope of the infrastructure conception have been adequately defined, it turns out to be absolutely necessary in characterising the interdependence of the basic and ancillary factors in modern social production.

Infrastructure is a conception that must reflect the tendency of the growing role of the production of information in the development of the modern economy as a complex system. This tendency springs from the fundamental shift in the very basis of human civilisation, as information factors steadily take over from material and energy factors. Information, as an aggregation of social knowledge, is increasingly capable of compensating for the shortage of material and energy resources, or to be more precise, of effecting the substitution of available for unavailable resources. In this sense, one could say that modern production has an information-communication infrastructure consisting of an aggregation of the facilities for storing, processing and transmitting information in sign and material form. [2]

The development of the infrastructure reflects the new stage in the social division of labour brought about by the scientific and technical revolution and the faster growth of sectors which are more immediately connected with the transformation of science into an immediate

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[1] In the USSR, "infrastructure" is a term used to designate the aggregation of structures which are external to the given line of production (sector) but which are necessary for its normal development. Social property in the means of production makes it possible to include the development and financing of the infrastructure in the state economic plan, taking account of its much greater asset-intensiveness, the long-term nature of the inputs and their low profitability, something that cannot be done under private property in the means of production.

[2] See, V. G. Afanasyev, *Social Information and the Governance of Society.*

productive force. First of all, there is, in accordance with the traditional classification, a redistribution of the active population between the sphere of material production and the nonproduction sphere, with the fastest growth taking place in the sectors most closely connected with the infrastructure. Thus, between 1965 and 1975, employment in Soviet agriculture and forestry fell from 31 per cent to 23 per cent, while going up in industry and construction from 36 to 38 per cent. Meanwhile, in transport and communications it increased from 8 per cent to 9 per cent, in trade, public catering, material and technical supply and marketing, and procurement, from 6 to 8 per cent, and in public health, physical training and social security, education, culture and art, science and scientific services, from 14 to 16 per cent. [1] We find a similar trend in other socialist countries.

The highest rate of growth has occurred in science and the scientific services. Here, between 1965 and 1973, employment in Bulgaria went up from 21,600 to 66,500; in Rumania, from 59,000 to 78,000; in Czechoslovakia, from 148,000 to 167,000; in Poland, from 50,000 to 134,000; and in the USSR, from 2,625,000 to 3,735,000. [2] Taking the Soviet Union's 1940 figure as a base of 100, we find that in 1975 it reached 1,150 having developed twice as fast as the sectors of the economy with fastest growth. [3]

The total number of persons engaged in research development and application of their results in the economy went up from 2.1 million in 1959 to 4.1 million in 1969. [4]

The data on the growing expenditures are also an indication of the rapid rise in the role of science within the infrastructure of social production. In 1940, science received only 0.6 per cent, and in 1950, 1.3 per cent of the expenditures of the USSR State Budget, by 1970 its share grew to 4.2 per cent, and by 1977, to 7.7 per cent. Consequently, the total outlays on science and education

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[1] *The USSR in Figures in 1975,* p. 171.
[2] *Statistical Yearbook of the CMEA Member Countries,* 1974.
[3] *The USSR in Figures in 1975,* pp. 176, 177.
[4] *Economic Problems in Enhancing the Efficiency of Research Projects,* Ed. by V. S. Sominsky, Leningrad, 1972.

came to a quarter of the budget.[1] Despite the different growth rates, the dynamics of the outlays on science has been invariably based on a consistent enlargement of the educational infrastructure. The scientific and educational infrastructure constitutes a coherent system which tends to become the key sector of the overall economic infrastructure, increasingly permeating every sector of the economy.

That is the basis on which the country's whole intellectual potential, with its scientific, educational and general cultural components, tends to develop. Thus, acceleration of scientific, technical, economic and cultural progress is a crucial condition for enhancing the efficiency of modern social production.

The Resolution of the 25th Congress of the CPSU laying down the guidelines for the USSR's economic development for 1976-1980 says that "successful development of basic and applied research has contributed to the solution of highly important economic problems, and has made possible fresh outstanding achievements in various fields of science and technology".[2] An example is offered by the experience of the Likhachov Motor Works in Moscow, one of the country's largest, which cooperates with nearly 50 scientific organisations. A group of scientists of the Institute of Chemical Physics of the USSR Academy of Sciences, led by Nobel Prize Winner Academician N. N. Semyonov, together with workers of the Chief Constructor's Department at the Works, headed by Merited Worker of Science and Technology of the USSR Professor A. M. Kriger, designed a precombustion-chamber flame ignition engine, whose use in the economy will help to cut fuel consumption by 10-12 per cent, with much less toxic emissions. A state commission has recommended the engine for mass production.[3]

The ever more important role played by science within the infrastructure of social production provides a most

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[1] Estimated by the author.

[2] *Documents and Resolutions. XXVth Congress of the CPSU*, p. 176.

[3] A. I. Volsky, A. S. Kobzev, *Alliance of Science, Technology and Production* (Experience of the Likhachov Motor Works Production Association), Moscow, 1976, p. 34 (in Russian).

telling argument against the theory of "saturation" in the industrialised socialist countries, which are said to follow in the wake of the capitalist countries. Economic factors indicate that the science-intensiveness of the economy under socialism has no bounds for the simple reason that it tends to grow, instead of diminishing, with the increasing efficiency of the economy as more and more science is applied to it. The latest scientific and technical achievements tend to become an organic "means of production" in every sector of the production and non-production sphere, without exception. This increasingly applies to scientific and technical personnel, demand for whom outside scientific research proper tends to outrun demand even in science itself. Alongside the comprehensive automation of production, control and management of economic development, the changing proportions within the "science-technology-production" system, and the immensely more important role of science in the development of production and society as a whole are another substantial feature of the scientific and technical revolution, if it is considered in the most general terms.

The prominent role of science within the infrastructure of socialist society shows that its positions are being increasingly fortified in the historical contest between the two world systems.

With the development and extension of scientific activity, its own information and communication infrastructure becomes as important in social production as the economic infrastructure. The information and communication infrastructure of scientific activity includes libraries, information centres and services, and computing centres linked up with the State Automated Control System, which is being built up in the Soviet Union and which is to constitute a single whole with the scientific and technical information system.[1] The infrastructure of scientific activity also includes the transport and communication facilities catering for it. Seen from this angle, the information and communication infrastructure of scientific activity constitutes a kind of nervous and partially vascular system linking up individual science cen-

[1] See, V. G. Afanasyev, op. cit.

tres and institutions and ensuring their normal vital activity.

Not only is the infrastructure of scientific activity functionally homogeneous with the infrastructure of material production, but it is inseparable from it. The same means of communication cater for scientific and other than scientific needs. But scientific activity depends on the information and communication infrastructure to a greater extent than perhaps any other sector. The development of the infrastructure largely determines the establishment, location and growth of the science centre network, the science cities, which gradually change the face of civilisation. The level of the information and communication infrastructure determines the very make-up of scientific activity and its intensity, the extent and scale of contacts among scientists, and has a direct effect on their productivity. The same factor facilitates the mobility of scientific personnel both on a national and a global scale. This has a substantial effect on the efficiency of scientific activity and of the whole of social production at the various stages and levels.

Inner-Science Balance

Advancing along the system hierarchy, we reach the next criterion, that of *inner-science balance*, a criterion which relates to the selection of alternatives within the framework of science itself. It is no secret that such selection is now effected empirically and even arbitrarily, with the advantages going to the scientific disciplines in which the scientists carry the greatest weight and influence, something that does not always correspond to the objective importance of their field.

Dr. Alvin M. Weinberg, Director of the Oak Ridge National Laboratory, expressed a view which has been widely accepted in the world's scientific literature, and which says that preference should go to the science which does the most to promote advance in allied sciences. But it is equally well known that this approach has not been extensively applied in practice.

One of the reasons here, I think, is that in the present conditions the discipline approach is itself obsolete, as scientists have increasingly to deal with interdisci-

plinary comprehensive problems. This is reflected in the practice of planning scientific and technical development in the socialist countries. Since 1969, the USSR has had planning procedures based on long-term (10-15 years and more) scientific and technical prognoses on the key problems, and these are used to lay down the main lines of scientific and technical development over the five-year period.[1] Long-term forecasts and plans reaching into the 1990s are based on what L. I. Brezhnev described as "supremely accurate and scientifically grounded computations, up-to-date methods of management and planning and the latest organisational and administrative patterns".[2] Here, account is taken of scientific and technical achievements like the use of high-temperature plasma and other new sources of energy, laser techniques, electronics, microbiology, bionics, use of the resources of the World Ocean, development of trains travelling on a magnetic or air cushion, and other new types of transport, and also the perspectives in the further exploration of space and the new potentialities opened up with the establishment of the automated control system.

In this context, there is an urgent need to restructure the whole system of organisation and control of scientific and technical progress on an interdisciplinary and goal-oriented programme basis. Here, the main criterion is the hierarchy of maturity and importance of the scientific and technical problems. Production and science-production associations become the main unit of production, while the project-type complex scientific team, bringing together scientists and specialists from various fields of knowledge, becomes the main unit in scientific activity.

"Especially meaningful at the present time," say two Soviet authors, "are problems in planning, organisation and control of complicated comprehensive programmes bringing together large teams of scientists and specialists from various fields, and vast material and financial resources.

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[1] From 1971 to 1975, about 240 key scientific and technical problems bearing on the intensification of social production were elaborated. From 1966 to 1975, 41,278 new types of machines, equipment, apparatuses and instruments were developed in the USSR (*The Economy of the USSR in 1976*, Moscow, 1977, p. 171).

[2] *Pravda*, March 21, 1972.

"In their day-to-day work, the leading scientists responsible for the formulation of a new scientific problem as a whole or of its individual parts, must be sure that:

"there are no superfluous works in their plan which are not necessary for attaining the goals of the organisation under the given topic;

"their plan does not neglect works necessary to attain the final goal in the elaboration of the topic;

"they are aware of the works any delay in the fulfilment of which is bound to upset the fixed deadline for completing the whole range of works on the topic." [1]

These requirements, for instance, are met by systems of goal-oriented planning of R & D, like the Sputnik and Skalar, which have been worked out in the USSR, and which are grid-method based machine information systems for the management of comprehensive scientific programmes.

But practice shows that the more thoroughly elaborated and "stringent" the control system for this or that scientific and technical programme, the more precisely it should dovetail with other programmes, with the meta- and macrosystems of control of science, technology and the economy.

As a matter of fact, the switch to grid methods of goal-oriented planning at the tactical level can succeed only if it is complemented (on the principle of external complement) with a switch to goal-oriented programme planning and control of scientific and technical progress of the strategic level, within the state's science and technology policy. Among the recommendations produced by a conference-seminar, "Use of Goal-Oriented Programme Principles in Planning and Control of Scientific and Technical Progress", organised by the Science Council of the State Committee of the USSR Council of Ministers for Science and Technology in Vilnius in September 1972, is the idea that the elaboration and fulfilment of full-scale goal-oriented programmes could ensure the solution of scientific and technical problems facing the state as a whole, the Union republics, the sectors and the firms, on

[1] V. G. Afanasyev, V. S. Chesnokov, "Goal-Oriented Planning Systems, an Instrument of Efficient Control of Research". In: *Scientific Governance of Society*, Ed. by V. G. Afanasyev, Moscow, 1972, pp. 268-69 (in Russian).

a high scientific and technical level and within the most appropriate periods.

This will be seen, in particular, from the experience gained in goal-oriented programme in planning and control of scientific and technical progress in Lithuania and its individual industrial associations like Sigma. While the resource-sectoral principle is based on a selection of ministry and department proposals and on the balancing of product resources and raw material resources, equipment and manpower, and frequently fails to take due account of national and republican needs, the goal-oriented programme principle makes it possible to start from the goals of the republic's economic development, and to consider resources and alternatives for using them and extending the potentialities and modes of attaining the set goals. Here, the Union republic's programme for scientific and technical progress is simultaneously a subprogramme of the programmes for the country's scientific and technical progress and of the republic's economic development. [1]

The need to pass on to goal-oriented programme planning and control of scientific and technical progress is dictated by life itself. A sizable number of sectoral research, design and technological organisations have already been integrated with the corresponding science-production complexes which are run through associations. As experience, notably that gained at Sigma, shows, the importance of science-production associations, in which the functions of the general managing board is exercised by the leading scientific research or R & D organisation of the science-production complex constituting the association, is bound to grow over the long term. [2]

Finally, on the last rung of the system hierarchy is the criterion of *inner-problem balance*, which is designed to maintain the necessary proportions between the various forms (stages) of R & D. Scientific activity today is a complicated system, whose structure and dynamics are largely determined by the balance between all kinds of

[1] See, *Proceedings of a Conference-Seminar on the Use of Goal-Oriented Programme Principles in Planning and Control of Scientific and Technical Progress, Vilnius, September 1972,* Vilnius, 1972, pp. 9, 53.

[2] Ibid., pp. 71-72, 14, 26, 31-34, 35, 72-74.

R & D. Science is an open probability system, and all the forms of R & D which it comprises differ only in the degree of indefiniteness of the expected results, which is at a maximum at the stage of basic research and at a minimum at the stage of development. Consequently, the need is to ensure rational proportions between pure and goal-oriented basic research, applied research and development, a problem which could be designated as one of maintaining the vertical proportionality of scientific activity. The most rational proportions between these forms (stages) of R & D (in the concrete conditions) have by now been established empirically, but there is considerable difficulty in maintaining them in practice. So, the needs of the economy may result in a spontaneous furtherance of applied R & D to the detriment of basic research, and of technico-technological projects to the detriment of scientific research, and also of applied research to the detriment of development.

Here, national traditions and the specific conditions in the individual countries are highly important. Whereas the United States has always been a country of mainly applied research and especially of development, European countries have just as traditionally given priority to basic research. In Russia, science has developed in this European tradition, and this is of especial importance now that the USSR ranks along with the United States as the world's leading scientific and technical power working over the whole R & D spectrum. However, so far the proportions between the main types of R & D which have taken shape are far from being ideal.

Priority should clearly belong in every case to the forms and lines of research which ensure the greatest progress along the whole front of science and technology, instead of yielding some immediate benefit. This requirement is best met by basic theoretical research, and its stable growth guarantees the overall development of scientific activity, whatever the socio-economic complications may be. That is why no economies in developing basic, academic science can be justified on any grounds of current considerations.

Of course, one should not turn a blind eye on the difficulties arising from the financing of basic research from the state budget. The financial agencies' control

functions are complicated by the high degree of risk and the indefiniteness of result, together with the need for broad creative freedom for the researcher. But, first, refusal to provide adequate finance for basic research is latent with much greater risk, that of lagging behind in the crucial scientific, technical and economic fields. Second, the relative magnitude of outlays on basic research is on the whole insignificant (only a few per cent of the cost of development, the testing of pilot models, and their engineering). Control of basic research should rest on independent expertise and should not hamper the freedom of the scientist's creative quest.

Both basic research and the applied research resting on it have now been institutionalised in the form of research institutes. The tasks which Decree No. 760 issued in September 1968 by the CPSU Central Committee and the USSR Council of Ministers set before Soviet research institutions require the elaboration of new, more flexible and efficient forms of organisation and management of applied research institutes.

The stage of development continues to be something of a bottleneck both in terms of financing and of organisation of scientific activity. The efforts being made at this stage are still inadequate. While development is the most capital-intensive part of the research process, being many times more costly than applied and especially basic research, much less is being spent in some sectors on development than on applied research.

Inadequate financing of development is compounded by defects in organisation at this crucial stage in the vertical transfer of technology. This applies above all to the thin infrastructure of development, which includes all kinds of pilot installations and experimental lines of production. The weakness of this extremely important link results in a definite gap between the latest achievements in science and engineering and their application in production.

The importance of making practical use of the results of scientific activity, as a Bulgarian student of science notes, [1] makes one turn to an analysis of the complicated

[1] Naiden Monchev, "Development and Innovation", *Science of Science Analysis*, Sofia, 1976 (in Bulgarian).

process of scientific and technical innovation by means of which the scientific idea or invention is realised in a product which makes economic sense.

An analysis of the process of innovation suggests that it runs through three stages. The first is that of development, which is simultaneously the final stage of research, when the initial ideas are analysed, the results of basic and applied research are synthesised, and models for production are elaborated. The second stage is that of engineering, which ends with the launching of an experimental series of the new product or experimental trial of the new technological process. The third stage is industrial mastery at which production acquires optimal scale. Here, development regulates and stimulates the realisation of the subsequent processes which provide the criteria for judging the correctness of the decisions taken at the development stage.

Scientific and technical innovation is among the "border-line processes", for, on the one hand, it is the result of scientific cognition, and on the other, of the development of production and the economy as a whole. Because innovation is attendant with certain risk, the institutions engaged in innovation need to be especially flexible, but this does not rule out stability of some basic aspects of their activity. In particular, there is need for functional, structural and information stability. The importance of planning, control and coordination tends to increase with the passage to each successive stage.

The constant reduction of the time interval between discovery and practical realisation is among the specific features of scientific and technical innovation. In addition, the change of technical approaches and principles appears to run along a spiral: many models, once rejected as being obsolete, tend to be used again later, but on a fundamentally different basis.

Successful scientific and technical innovation is an important factor in the development of science itself, because it confronts scientists with new problems. Monchev draws the conclusion that there is positive feedback between scientific and technical innovation and the development of science.

The process of innovation is influenced by a number of factors closely connected with the level of society's

socio-economic development. "On the socio-political system depend not only the consequences of applied innovation, but also the very possibility of effecting this process." [1]

An analysis of the structure of the "research-production" process carried out in Leningrad has helped to establish that in the engineering and instrument-making industries the stage of applied research lasts averagely 25-30 per cent of the overall time (equal to 6-9 years), experimental development, 30-40 per cent, and starting of industrial production (including the stage of economic assimilation), 15-35 per cent, while the intervals between stages come to about 10 per cent (mostly between the stages of development and production).

In the chemico-technological industries, the figures for the processes in developing new hardware and products requiring design and construction of new production areas are, respectively: 15-20 per cent, 35-60 per cent and 15-25 per cent. The breaks (especially between the stages of applied research and experimental work, when new installations have to be set up) come to 15-20 per cent of the total time.

Processes including the stages of design and construction have a somewhat different structure. Here, applied research and experimental work takes up 25-30 per cent, industrial design 15-20 per cent, construction 20-30 per cent, and mastery 30-35 per cent of the total time taken by the "research-production" process.

In present-day conditions the overall time taken by development and mastery of new hardware becomes an important measure of the quality of control of scientific and technical progress. Some studies suggest that a large part of the development projects are wound up short of application; some are either not used at all or are applied with such delay that the hardware developed on their basis turns out to be below the world standard. The percentage of scientific projects not applied in production is still high. [2] Meanwhile, various methods helping to move new

[1] N. M. Monchev, "Methodological Aspects of Scientific and Technical Innovation", *Philosophical Thought*, Sofia, 1973, G-29, Book 8, p. 82 (in Bulgarian).

[2] *Economic Problems in Enhancing the Efficiency of Research Projects.*

ideas into production much faster are being ever more widely accepted in the Soviet practice of controlling scientific and technical progress. In Leningrad, a team led by Professor V. S. Sominsky has estimated the time these methods have helped to save (Table VIII-1).

The organisational snags in application are rooted in the economy and in the inadequacy of the material incentives being applied. Elaboration of the incentives system as an inducement to more rapid application of promising scientific and technical ideas both for those who work in production and for scientists still faces considerable difficulties. At the same time, there are many positive examples in the resolution of the economic contradictions, above all in the activity of the front-ranking combines, industrial and science-production associations, and also of other forms of science-production complexes. They have gained highly positive experience in reducing the R & D cycle and accelerating the process of application. The initial efforts by such complexes and associations in construction have also proved to be successful. [1]

A Czech student of science, Jaroslaw Kubík, says that an average of about one-third of the total volume of works in a science-production association goes into R & D. Compared with research institutes, science-production associations have a number of important advantages, like simplifying the unification and standardisation of products, accelerating the pace of application, and making the use of production programmes much more flexible. Besides, within the framework of the associations production can exert a direct influence on science and swiftly respond to the results of research. The author notes that the USSR's experience confirms the fact that science-production associations have justified themselves above all in batch and mass production. [2] The establishment of production associations is a new and important element in improving the management system. Their development helps to make fuller use of the available potentialities and accelerate scientific and technical progress. Improvement of the organisation and control of science is closely

[1] See, P. Voroshilov, "The Firm Helps the Inventor", *Izvestia*, September 10, 1970.

[2] J. Kubík, "Racionálni formy spojeni vyzkumu a vyroby", *Plánované hospodarstvi* No. 10, Prague, 1973, pp. 16-31.

Table VIII-1

Fffective Ways of Cutting the Duration of the "Research-Production" Process

Ways of cutting duration	Cuts in length of stage, years	Cuts in length of process, years
Organisation improvement	0.1	0.25
Use of standard schemes for works production	0.25	0.25
Use of standard design methods	—	1.5
Automation of individual operations	0.25	0.25
Use of mathematical modelling methods	1.0	1.0
Use of net planning and control systems	0.25	0.25
Establishment of science-production associations	—	1.5
Use of through-put planning of process	—	1.0
Improvement of organisation of systems for transfer of technical documents to enterprise	0.25	0.25
Other methods	0.25	0.75
Total	—	5.0
Possible duration of process (with average duration of the R,D,E and M chain, equal to 8 years)	—	3.0

Source: Economic Problems in Enhancing the Efficiency of Scientific Projects.

bound up with the material back-up of science's leading role in the development of the socialist economy today. [1]

A survey of research, development and technological organisations, complex science institutions, production associations with scientific and technical organisations, and

[1] V. Sominsky, "Standard of the Sector", *Pravda*, November 27, 1973.

academic institutes with design offices and experimental production areas, carried out in Leningrad by the Zhdanov University shows that in complex organisations the duration of the research-production process is reduced by 15-20 per cent, with efficiency of activity being 50-100 per cent higher than it is among separate scientific and technical organisations and enterprises. [1]

There is a need further to improve the mechanism helping to reduce the time it takes to apply scientific and technical achievements in production. Not only scientists and inventors but also workers in production should have an interest—both moral and material—in doing this. Many ways have been proposed for overcoming the obstacles which make it more difficult for science and production to interact, but primary importance, I think, attaches to those which help to set up a constantly operating organisational mechanism for improving the "research-production" system in the light of changing conditions. This requirement is met above all by a restructuring of scientific activity at the interface between the institute and the plant, where science-production complexes are now the leading form.

Things are more difficult for institutes and plants which because of their specific features cannot be included in associations, although they have to cooperate closely in realising scientific and technical innovations. This applies to a number of sectors in the extractive industry and also to some sectors in manufacturing where small batch production predominates. But in these cases too the principles adopted in science-production complexes for restructuring the relations between scientific and production organisations have yielded fruit.

What then should such a restructuring amount to? Soviet and foreign experience shows that it should be based on a switch from the now prevailing functional structure of research institutes, where laboratories, sectors and departments are organised by specialty, to the problem structure under which specialists from various fields make up teams to tackle definite problems, with these problem teams being swiftly formed and dissolved as the

[1] See, *Economic Problems in Enhancing the Efficiency of Research Projects*,

need arises. The advantage of problem structures over functional structures lies in the fact that they are much more flexible and that in consequence their work is more purposeful and efficient. Experience shows that the socio-psychological and organisational difficulties arising from such restructuring are quite surmountable and are more than compensated by the resultant benefits. Thus, the restructuring of the All-Union Gas Research Institute from a functional to a problem arrangement, with a simultaneous build-up of its development section, helped within two years to halve the average time it takes to realise research topics, and considerably to speed up the application of the results of research.

When switching to a problem structure it is advisable in some cases to separate the scientific-technical control and the administrative management. This could be done roughly on these lines. To realise a long-term idea, a problem team is set up at the institute under the scientific leadership of the author of the project or some leading scientist. The chief engineer (or another responsible worker) of the enterprise which is to apply the innovation is appointed as the administrative head. Of course, this separation of functions should be preceded by the establishment of good relations between the scientists and the production practitioners, say, in the form of a contract on creative cooperation. As the project moves into its final stage, more and more workers of the enterprise could be included in the team.

Experience shows that such cooperation is highly effective, and one example comes from the joint work of the sheet liner laboratory at the All-Union Research, Design and Technological Institute for Asbestos Technical Products with the Moscow and Barnaul enterprises turning out technical asbestos products. As a rule, the head of the institute laboratory is appointed the leader of the joint project, and the chief engineer of the enterprise, his deputy. The former is responsible for the quality of the specifications and the production techniques, and the latter for organising the experimental production area, provision of raw and other materials, adjustment of the production techniques, and so on. This helped to enhance the stake in the project of the institute and the enterprise. As a result, the batch production of fundamentally new

packing materials now takes one year to arrange, instead of the two to five years.

Creative cooperation among scientists and workers in production helped to engender a "contract commitment" concluded by the collectives of the All-Union Metal and Machine Research Institute, the Serp i Molot Works, the Moscow Institute for Steel and Alloys, and the Moscow Evening Metallurgical Institute, which undertook to work together to solve the problem of technical re-equipment of the Serp i Molot Works, to convert it into a front-ranking and model metallurgical enterprise. With that end in view, they set up a joint no-payroll design office, headed by Academician A. I. Tselikov, Director of the All-Union Metal and Machine Research Institute.

There teams of developers were set up for steel smelting, section rolling and sheet rolling, each consisting of scientists and specialists from the enterprise. The number of institutes taking part in the work of the teams was also increased, including the Central Research Institute for Ferrous Metallurgy and other institutes.

The acceleration of scientific and technical progress largely depends on the sound alliance of scientists and workers in production. Dozens of institutes, design offices and plants in various industries were involved in elaborating new methods of plasma welding, the synthesis of artificial diamonds and other superhard materials. Within three or four years, hundreds of enterprises were making use of their results.

In the recent period, various efficient forms of closer association of science and production have been tested in practice. The comprehensive programmes for cooperation between the Siberian Branch of the USSR Academy of Sciences and various sectors of the economy deserve attention. Through-put planning of every stage in the development of new hardware is being successfully applied at the Ministry of the Electrotechnical Industry. Many institutes of higher learning and enterprises have worked out joint plans adjusted upward as compared with the original. New remuneration systems for scientists and improved methods of work organisation are being tested experimentally.

Reduction of the way an idea has to travel to its application through a switch from series to parallel orga-

nisation of development project has justified itself both in relations between the research institute and the plant, and also between various scientific and technical services at the plant itself.

A group of designers at a Lvov enterprise says: "Other forms of close cooperation, parallel action by designers and technologists have also acquired highly concrete outline. While the instruments are being developed, we try to find out how they will fit' into the assembly lines and suggest what should be done to change or restructure these. That is why one will never hear anyone here saying things like 'half-baked project' or 'half-baked scheme'. What is more, everything that is required for starting batch production is being prepared in our shops simultaneously with the development. Thanks to our mutual understanding with the designers, we have succeeded in reducing the number of new pieces of rigging that need to be fabricated from scratch (and everyone knows that this costs a lot) from 500 to 50-70 units per product. This has markedly eased the burden falling on the back-up production area, especially tool-making." [1]

The new system of economic incentives and material inducement at the research institutes has made the size of the inducement funds directly dependent on the actual economic effect in the economy from the use of the scientific and technical projects and new hardware. But this relates only to the bonus system. One line for improving the system of remuneration for scientific workers is improvement of the organisation of their basic salaries through a link-up between these and every individual's actual results.

In the past few years, a number of measures has been taken to improve the system of remuneration for scientific workers.

Since 1968, in accordance with a decree issued by the CPSU Central Committee and the USSR Council of Ministers, "On Measures to Enhance the Efficiency of the Work of Scientific Organisations and Accelerate the Use of Scientific and Technical Achievements in the Economy", the heads of enterprises in industry, of design of-

[1] V. Vulkovich, S. Tsikora, "Under One Roof", *Izvestia*, August 5, 1969.

fices and technological organisations have the right to allow higher basic salaries, in accordance with salary standards at research institutes, for specialists who hold scientific degrees and who work in their proper line.

Since 1969, under a decree issued by the USSR Council of Ministers on salaries for workers at research institutions, design offices, technological organisations and computing centres, the remuneration of their labour has been adjusted, a new standardised salary system approved, and the heads of these institutions empowered to allow increments to salaries of up to 30 per cent of their basic salary within the wages fund for scientists, engineers, technicians and other specialists without scientific degrees, making use for that purpose, and by consent with the superior agency, of up to 2 per cent of the planned wages fund of the institution (workers' wages apart).

For the purpose of making the most rational use of specialists, for determining the business qualities of personnel and deciding on whether they qualify for their posts, the State Committee of the USSR Council of Ministers for Science and Technology and the State Committee of the USSR Council of Ministers for Construction have approved a set of procedures for the certification of personnel at research, design, development and technological organisations. [1]

In the summer of 1974, a poll was taken on various aspects of certification and remuneration of labour among scientific workers in the USSR. More than 6,000 scientists across the country replied to the questionnaire. When asked to designate the most popular changes in the remuneration of labour, most (32.4 per cent) gave preference to the proposal to have scientists' salary consist of two parts: a guaranteed minimum for each category of scientists and payment for performance.

Second (30.0 per cent) was the proposal to increase the number of basic scientific posts (instead of the two existing ones of senior and junior research associates, to introduce four or five), thereby making for more differentiated remuneration of scientists' work.

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[1] See, *Economic Problems in Enhancing the Efficiency of Research Projects.*

Third place (26.8 per cent) went to the proposal to enlarge the "bracket" between the salaries of senior and junior research associates, so that the two would partially overlap. The suggestion was that within each "bracket" salaries should be allowed for a period of three-five years, depending on qualification and the actual output, in accordance with expert evaluation. It was also suggested that scientific degrees should not be of decisive importance, but that account only should be taken of them by the number of points, alongside the quantity and quality of the papers published in that period, author's certificates awarded, the economic effectiveness of applied projects, and so on.

Finally, last on the list was the proposal to have salaries depend only on the post held, and to abolish any increments for scientific degrees and titles.

The above system of criteria for selecting the main lines in science is the basis of the mechanism for decision-making in science policy.

This mechanism can function on the basis of a model proposed by Erich Jantsch in the form of this matrix:

	A) Policies	B) Strategies	C) Tactics (Operations)
1. Forecasting			
2. Planning			
3. Decision-making			
4. Rational creative action			

Source: Erich Jantsch, "From Forecasting and Planning to Policy Sciences". In: *Management of Research and Development*, Paris, 1972, pp. 141-46.

The only thing that needs to be done is that at every stage in implementing this action matrix, the scientific and technical decisions should rest on the principle of external complement and should run from the metasystem to the system. It is socialism that is most adequate to this principle. The socialist planned system, as a UNESCO working document prepared for the Conference of Ministers of Science of European Countries in 1970

said, has the advantage that the leadership's decisions can be swiftly and smoothly transmitted to all the executive agencies in science policy. This same advantage makes it possible flexibly and freely to move material resources and personnel from one area to another. This is a reliable guarantee that the selected main lines will be successfully developed.

The socialist planned system also makes it possible to correct, without delay, any defects or mistakes against which no science and technological policy is guaranteed as it faces tasks of unusual complexity and novelty.

St. Dedijer is quite right in regarding science policy as "social innovation". He explains: "A technological innovation is an R & D product, an invention or a discovery that 'sells', in the narrow and the wider meaning of the term, i.e., that is socially accepted. Unlike technological inventions, social innovations do not come about 'suddenly' as the result of an idea on the part of one individual or several individuals at the same time. Social innovations are much more complex and ... they consist of a number of interacting 'soft' components." [1] As social innovation, science policy emerges in different ways, being a derivative of the country's specific features. But for all that, science policy still turns out to be social innovation for all the countries of the world and evidently has universal features which make it possible to identify it in any country.

In order to make the system of selection and decision-making in science policy more reliable and to reduce the probability of error to a minimum, there is an ultimate need to convert the science policy mechanism into

[1] According to Dedijer, the most essential "soft" factor which determines the line of science policy is the alignment and struggle of forces on the political scene in which science development problems are ever more frequently introduced as planks in party platforms. Analysing the matrix of Sweden's R & D appropriations, he shows that the changes in the matrix importantly depend on the parties in power. So, there may be sharp fluctuations in the incipient tendency for cut-backs in military R & D appropriations, moving in reverse when the "Right" take over, remaining unchanged when the "Middle" are in, and increasing sharply when the "Left" take over. (St. Dedijer, "National R & D Policy as a Social Innovation", op. cit., pp. 101, 108.)

a self-organising system. Steps in this direction are already being taken in the Soviet Union. The administrative powers and scientific rights of research institutions are being extended, and their display of initiative in tackling new problems is being encouraged. The science of science is developing, ever more confidently assuming the function of the theory of science policy.

As a result, the goals of science organisation strategy, above all the enhancement of economic profitability and of the social effectiveness of scientific activity, are becoming much more attainable.

Conclusion

With the advance of the current scientific and technical revolution, it is becoming increasingly clear that it amounts to more than revolutions in the various fields of science and technology, however profound and impressive these may be. The ongoing changes are extremely different in quality and in level. But they do all have a common basis, and this consists of the qualitatively growing role of scientific knowledge, on the one hand, and of the scientific organisation of labour and production, on the other.

The synthesis of science and organisation has been moving to the forefront of the scientific and technical revolution. With man's ever more extensive and vigorous influence on the natural environment of his habitat, there is an inevitable growth of entropy in the biogenosphere of the Earth: the so-called ecological crisis is only a manifest expression of it. To resist the devastating effect of the laws of thermodynamics, there is need to order to the greatest possible extent all the modes by means of which man masters reality, notably, the theoretical mode (science) and the practical mode (production).

The theoretical (scientific) mode of mastering reality is, in effect, designed to study the structure of the universe and the laws governing its change, so that its subject-matter is the world order and the ways in which mankind can use it. Consequently, ordering is the *raison d'être* of science itself, its "inner perfection" (Albert Einstein). The task is, therefore, to back it up with "external perfection", that is, the ordering of scientific activity itself.

The practical (production) mode of mastering reality is a different matter. Of course, here, too, the ordering of the universe constitutes the most immediate meaning of activity, regardless of whether it runs on a purely empirical or scientific basis. But in both cases the overall picture is much too complicated for anyone to foresee the ultimate effects of local influences. For instance, the priority development of some sector may occur at the price of a lag in other sectors, something that may eventually upset the overall economic proportions. Such "disturbances" can be prevented through the comprehensive planning of the economy on a coherent scientific organisational basis, and the conditions for this are provided only by socialist property in the means of production.

Science organisation, as a synthesis of science and organisation, serves as the basis for ordering in the theoretical science and practical production activity. Socially organised science moves into the leading place within the whole system of social productive forces and merges with the scientifically organised production. In this sense one could say that science organisation has a system-forming function with respect to society's productive forces. The ordering of the latter on scientific organisational lines emerges as the highroad of the scientific and technical revolution. The synthesis of science and organisation in the noosphere is designed to bring about a development of the scientific and technical revolution that would run along the whole front of theory and practice, fortifying, instead of undermining, the balance between the biosphere and the technosphere of the globe. The maintenance and ordering of this balance is a necessary condition for the survival and further development of human civilisation.

The synthesis of science and organisation at every hierarchic level is far from being effected without conflict.

At the microlevel of the primary scientific team, the synthesis of science and organisation is realised above all through a sharpening—and resolution—of the contradictions between nonconformism and conformism, the former being organically inherent in science as a form of human activity. Scientific knowledge is an endless approximation to the absolute truth along the stages of

relative truths. But virtually each of the latter claims to be the "last authority truth", becoming a paradigm, according to Thomas S. Kuhn's well-known expression.[1] In order to cross from the previous one to the next rung of knowledge, one has to surmount the generally accepted paradigm and the authorities who back it. That is why genuine science must necessarily be nonconformist and, indeed, revolutionary. Ascent along the endless ladder of knowledge must become an "escalation" turned against the organisational forms which stand on guard of the paradigm.

This is a dialectical process. According to Maurice N. Richter of New York University, in some cases the efforts to maintain the old theory result in additional research which eventually exposes its inadequacy. Consequently, the conditions which create difficulties for scientists might sometimes be beneficial to scientific progress.[2] Let me add, however, that this happens only when such resistance is not organisationally entrenched and is not developed into a "witch hunt".

The conflict evolution of the microlevel of science organisation, in accordance with the external complement principle, in itself needs to be complemented with the macrolevel. Here, the synthesis of science and organisation is expressed in the establishment of science policy as a new state function.[3] Science policy is expressed in the system of state measures taken to administer scientific activity, and its mechanism, in the system of agencies authorised to elaborate and implement these measures together with a set of relevant procedures. The state is the subject of science policy, and scientific activity is its object. The general line of science policy is control of the scientific and technical revolution, and this purpose is divided into subpurposes (with a diminishing generality) like ensuring equilibrium between society and the natural environment, between the given social system and its socio-political environment, within the given social

[1] See, Thomas S. Kuhn, *The Structure of Scientific Revolutions*, Chicago, 1970.

[2] Maurice N. Richter, Jr., *Science as a Cultural Process*, Cambridge (Mass.), 1972, p. 90.

[3] D. M. Gvishiani, *Organisation and Management. A Sociological Analysis of Bourgeois Theories*, Moscow, 1972.

system, notably, between science and the other sectors of social production, within science—between the various lines of research—and also between the individual categories (stages) of R & D.

In the USSR, attainment of the goals of science policy is being effected through an ever more extensive range of means and methods of state regulation of scientific activity, with the leading role belonging to methods of planning, and financing of scientific activity through the state budget in the form of subsidies or economic contracts, and also in the form of tax privileges, depreciation allowances, and so on. Juridical methods in science policy—like patent legislation—also have an important role to play. [1]

Among the science policy instruments are above all the governing system of agencies for administering science and the governed system of agencies for implementing R & D. Although historically the former system sprang from the latter as a peculiar "superstructure", it now has a structure-forming function, shaping the scientific and technical potential of modern states.

A distinction should be drawn between the technico-organisational and the socio-political aspects of science policy. The former is determined chiefly by the size of the state, the level of its economic, political and cultural development, and its traditions, and the latter, by its socio-political system, which determines the character of all the state functions, including the trends and perspectives in science policy.

Nicolas Jéquier, an associate of the Centre for Industrial Studies at Geneva, has forecast the end of science policy as amounting to state interference in the scientific system, in accordance with the established political principles bearing simultaneously—depending on definite goals—on the national interest and the interests of the scientific community. He says that the policy of states in

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[1] Some say that the unpredictable character of science makes any attempts to formulate "a policy for science" dubious. This view has been expressed, among others, by Dewitt Stetten, Director of the National Institute of General Medical Sciences in the United States. Still, in practice, planning of science and technology is becoming ever more important.

science which seeks to promote the development of science and, through its medium, the attainment of broader goals in industrial, economic and military spheres, is on the way out, despite the exceptional successes of the past ten years.

Jéquier reasons on these lines. The governments of Western countries lay claim to a science policy monopoly, but major private enterprises, and also universities, if they can find private sources of finance, or if they rely for aid on funds like the Volkswagen, Rockefeller or Ford Foundations, invariably remain outside the ambits of their science policy. The author says that it is time to abandon the claim of pursuing a single centralised national policy in the field of science, which should become federalist, synthesising the various lines of policy pursued by major and leading scientific organisations.

Jéquier goes on to say that since the early 1960s, science policy, like economic policy, has tended to become a macropolicy operating mainly with statistical data, in the process losing sight of the quality and internal mechanism of the scientific system. While science macropolicy concentrates on the material infrastructures, education and technical development, micropolicy, which now exists only in private industry, is oriented upon the research products of the most talented scientists. At the same time, the "system" or "interval" policy in the field of science is designed to effect intricate patterns in the science system, involving scientists, laboratories and national scientific communities. Jéquier suggests that if science policy is to be salvaged and made more efficient there is a need to combine the principles of all three levels of policy, and above all to increase outlays on information and communications.

Science policy can no longer confine itself to the original goals of university education and national defence. Its goals have become much broader and more complicated, because it now has the chief role to play in industry, agriculture and social relations. That is why science policy should be closely tied in with policy in technology and industry, as it is, for instance, in Japan. There is "feedback" between them. Meanwhile, science policy continues to start only from the "internal" goals of science and technology. Its "external", social goals

are usually ignored. Jéquier suggests that science policy should be galvanised through the attainment of an equilibrium between scientific, technical and social changes by controlling the process of innovation in the broadest sense of the word. There is a need to transform science policy into an innovation policy or to make it part of a policy whose goals are still to be defined. [1]

Much of this criticism is right, but the tasks facing science policy today are much broader. As a new function of the state, science policy is in complex interplay with all the old functions of internal and external policy. With the growing social role of science, it tends increasingly to permeate every line of state policy, like the whole of the state machinery. Scientific and technical expertise becomes a necessary premise for the adoption of any important domestic, foreign policy or economic decision, with men of science filling more and more posts in the agencies of state administration. This process tends to be markedly accelerated under socialism where socio-economic construction has a scientific basis.

On the other hand, science policy acquires ever broader general political significance. Control of projects in space exploration, construction of powerful atomic accelerators, radio telescopes, oceanographic vessels, and so on, inevitably affects the interests of a large number of ministries and departments, and becomes the subject of discussion in the organs of legislative power. Thus, in the United States the Mohole Project for drilling a super-deep hole in the Earth's crust, the project for building a 300,000 million electron-volt proton accelerator became the subject of acute political and party struggles, which were fanned by considerations concerning the potential "commercial fallout" and, most importantly, by the additional prestige to be got from realising such scientific projects.

The foreign policy resonance of some measures in science policy is even greater. During the cold war period it was expressed in the "Sputnik Shock" in the late 1950s. With the international detente the response is

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[1] N. Jéquier, "La fin de la politique de la science". In: *Revue économique et sociale* No. 2, Lausanne, June 1973, pp. 185-94.

naturally quite different. This will be easily seen from the evolution of the space programme which, once an instrument of political prestige and rivalry, has become an instrument of scientific and technical cooperation. This is an example which shows once again that science policy is increasingly becoming not only an object but also a subject of major political changes in the world arena. Thus, the joint development by scientists and specialists from the Soviet Union and France of the SECAM-III colour television system did much to develop contacts and normalise the situation in Europe in the 1960s. In the 1970s, scientific and technical ties between East and West in protection of the environment, the use of electronic systems for process control, the treatment of cardiovascular and cancer diseases, and so on, have an even more meaningful role to play. Here, the achievements of socialism in public health (like the Soviet "first aid" system) and of urban public transport have been attracting growing attention in the West.

Let me emphasise that the Comprehensive Programme for the Further Extension and Improvement of Cooperation and the Development of Socialist Economic Integration by the CMEA Member Countries, which has undoubtedly given an impetus to scientific and technical innovation, is of ever greater international importance today. The coordination of national science policy in the socialist countries shows very well that the individual countries must and can consistently concert their science policy acts on a mutually advantageous and equitable basis.

Science policy—the macrolevel of science organisation—has been exerting an ever deeper influence on its microlevel, on scientific activity as a whole. This is expressed in the formation and development of a network of science centres and institutions. The science administration agencies, which have taken shape as a control system, assume the role of a structure-forming matrix as a basis for the establishment of the scientific network. There is, first of all, a rapid increase in the number of scientific institutions being set up on the initiative of the scientists themselves, but always with the support of the state. The latter has been ever more actively coming forward with such initiatives as new and unmet scientific

and technical requirements appear, and the results are soon to hand.

The rapid growth in the number of scientific institutions has gone hand in hand with the snowballing in the number of contacts between these and also between them and other governmental and nongovernmental (for instance, public) organisations. These ties are not equivalent, for some are episodic, while most are highly stable. Some ties are productive in scientific terms, others are not. State science policy at this stage tends to move from direct control of the activity of the scientific institutions to the regulation of the scientific ties: the information character of scientific activity invests this instrument with the utmost possible efficiency. It now remains to select the ties which are most productive and stable, so as to ensure optimal conditions for their development. These include above all the association of institutions in contact with each other in complex and specialised science centres, each of which has to maintain stable ties with its other centres and also with the agencies implementing science policy. In other words, it has to be an open and not a closed system. But the main thing is that the solution of problems in modern science requires a pooling of efforts on a scale which goes well beyond the potentialities not only of individual science centres and institutions but of whole countries. Hence the need to bring individual centres and institutions together in a scientific network. This assumes the functions of the metalevel of scientific organisation ensuring the generation and realisation of scientific ideas by accelerating their movement along the vertical and the horizontal.

Along the vertical, the scientific network helps to accelerate the maturing of new ideas and the creation of what could be called their "resources". The right way to do this is to combine instruction at school and then at the higher school with research which helps to intensify the generation of ideas not only among the students but also among the teachers.[1] To achieve this, the latter must themselves be researchers. It is academic science that makes the best use of new ideas and their authors,

[1] See, V. G. Afanasyev, *The Scientific and Technical Revolution, Administration, Education*, Moscow, 1972 (in Russian).

which is why it has, by rights, the structure-forming role to play in shaping and development of the scientific network.

But as they mature, new ideas tend to break through the academic shell and require production realisation. Accordingly, academic and higher school science centres are "built up" with design, development and technological subunits for the elaboration of the most promising ideas.

At the present stage, the Soviet practice in organising the control of scientific and technical progress has put forward four main types of science-production complexes:

complex scientific and technical institutions concentrating research, design, development and technological work, with a developed experimental production area;

research institutes at major industrial enterprises or in production associations;

science-production associations which include research, design, development and technological organisations and industrial enterprises; and

academic institutes including design offices and experimental production areas. [1]

The system of science-production complexes helps to accelerate the spread of scientific ideas and their development along the horizontal, between geographical regions and production sectors. This has a positive feedback effect on the generation of new ideas, as a result of which scientific and technical progress is invested with a growing momentum. Consequently, the metalevel of the scientific network helps considerably to enlarge the ambit of ideas and brings closer together the micro- and the macrolevels of scientific organisation under the scientific and technical revolution.

The TV model of control of scientific and technical progress realised in this way organically combines the advantages of centralisation and decentralisation in the organisation of scientific activity, ensuring a sufficiently high concentration of effort. UNESCO's report, *Science and Human Needs*, said in this context that there were two different approaches to the planning of science. The

[1] See, *Economic Problems in Enhancing the Efficiency of Research Projects.*

first was usually called pluralistic and it shared responsibility for planning and decision-making among a large number of agencies, so that overall policy amounted to no more than an arithmetical mean of a whole spectrum of individual policies. The second approach was centralised, involving attempts to project the general national science policy into which the policies for the individual areas of science have to fit.

Both approaches have their advantages and shortcomings. Thus, the pluralistic approach provides the flexibility needed to satisfy a number of here-and-now requirements, and also for taking account of unforeseen events, which so frequently occur in the development of science, with a minimum of damage for the other sectors. But it also has the defect that it puts the long-term and short-term needs of the sector in direct competition with each other, with the result that the long-term needs could lose out, especially in periods when the overall resources at the disposal of the sector are limited or dwindling. The second defect is that the goals tend to become static, while new opportunities or goals based on new knowledge have a tendency to escape notice.

The advantage of the centralised systems is that they can help to make more efficient use of limited financial and personnel resources, thereby making the system as a whole more flexible and adaptable. One shortcoming, however, is that centralised planning can be less responsive to the operative needs of various sectors. This now and again produces ossified and conservative tendencies in sectoral policy.

In practice, each country seeks to strike a balance between these two approaches, and this best of all accords with its own approach to economic and social planning. Thus, even in the most highly centralised economic systems some advantages of decentralisation of individual aspects of planning are realised; similarly, countries with the private enterprise economic tradition begin to realise the need for integral planning, especially in the epoch of "Big Science", which can develop only with a definite degree of centralisation. Most large corporations in the science-intensive sectors have accepted such a balance as a basis for their research planning strategy. They frequently have research divisions at each of their

operative or production subsidiaries in addition to the corporation laboratory engaged in long-term research for the purpose of developing new products and processes and providing a general scientific and technical basis for all the acts and decisions of the corporation.

However, in practice, the effectiveness of science policy appears as a direct function of the measure of concentration of scientific activity, ensuring a harmonious balance between centralised state direction of science "from outside" with the steady development of the mechanism of its self-organisation "from inside". Advancing along this way, science policy seeks to attain marginal effectiveness beyond which its historical mission changes. Science policy becomes an ancillary mechanism of the integral or "universal intellect" (Karl Marx) to the extent to which the latter is a mechanism of the noosphere envisaged by V. I. Vernadsky [1] and also by Pierre Teilhard de Chardin. [2]

At the same time, in accordance with the external complement principle, the existing and any possible future contradictions in science policy will be resolved in the metasystem which will in turn become a reality only by acquiring historical experience in such resolution. The society in which this will become possible must be free from every form of oppression, exploitation and social injustice.

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[1] V. I. Vernadsky, *The Chemical Structure of the Biosphere of the Earth and Its Environment*, Moscow, 1965, pp. 323-31 (in Russian).

[2] Pierre Teilhard de Chardin, ***Le phénomène humain***, **Paris**, 1955.

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